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ABSTRACT

This study examines the effects on long-term retention of variations in intensity and temporal parameters of arousal following a single learning trial in a paired-associate task. Intensity of arousal was manipulated by using two levels of noise, 75 db. and 90 db., and a condition without noise. Noise was delivered to the 56 female university student subjects at 0-3 minutes, 3-6 minutes, and 6-9 minutes following a learning trial. The main effect of level of arousal was not significant. However, the results do tend to indicate that a moderate level of arousal induced between 6-9 minutes is conducive to the consolidation process, resulting in superior long-term recall. The results are discussed in terms of a multi-stage analysis of memory consolidation and directions for further research are outlined. (Author/TL)

INFLUENCE OF TEMPORAL PARAMETERS AND INTENSITY OF POST-LEARNING AROUSAL CHANGE ON LONG-TERM RETENTION

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

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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 processes 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 the improvement of educational practice.

This Technical Report is from the Motivation and Individual Differences in Learning and Retention Project from Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, the Learning and Memory Project has the long-term goal of developing a theory of individual differences and motivation. The intermediate objective is to generate new knowledge of the learning and memory processes, particularly their developmental relationship to individual differences and to motivation.

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ABSTRACT

The present study was designed to examine the effects on long-term retention of variations in intensity and temporal parameters of arousal following a single learning trial in a paired-associate task. The Ss were 56 female university students.

Intensity of arousal was manipulated by using two levels of white auditory noise, viz., 75 db. and 90 db., and a condition without white noise. Noise was delivered to the Ss through earphones at three different temporal intervals; viz., 0-3 min., 3-6 min., and 6-9 min., following a learning trial.

The main effect of level of arousal was not significant. As regards temporal intervals, it was found that 75 db. of white noise delivered between 6-9 min., had significantly higher recall when compared with a combined mean of all the other conditions ($p < .02$). Individual contrasts with each group mean revealed that the 75 db., 6-9 min., group was not significantly different from the no-noise group and the 0-3 min. groups at both levels of noise. The recall scores were lowest for 3-6 min. groups at both levels of noise, significantly less than the 75 db., 6-9 min., but not significantly different from the no-noise group. The results were discussed in terms of a multi-stage analysis of memory consolidation and directions for further research were outlined.

I

INTRODUCTION AND REVIEW OF THE LITERATURE

There seem to be three crucial issues in the perseverative theory of consolidation of memory as related to arousal; Viz. (1) duration of the perserverative process; i.e., the time of its initiation and its termination, (2) the optimum level of arousal that will facilitate the perseverative process and consequently lead to firmer fixation of the memory trace, and (3) the optimum temporal point of action of arousal whether during trace formation, trace storage of consolidation, and trace retrieval. A fourth issue could be the appropriate catalyst or means of influencing arousal. For the purposes of this report the discussion would be centered on the first three issues.

There have been several studies demonstrating evidence of the presence of certain continuing neurological events [as originally proposed by Muller and Pilzecker (1900)] initiated by learning with the intensity of these events subsiding over time. If uninterrupted, this perseverative activity has the effect of strengthening or consolidating the learned associations [Thompson, Haravey, Pennington, Smith, Garron, & Stockwell, (1958)]. Additionally, with appropriate stimulation, it is possible that the perseverative process may be accelerated thus facilitating retention and resistance to post-learning interference.

Several techniques have been employed in studies in this area, including electroconvulsive shock (ECS) and stimulant and depressant drugs with animal subjects. In the area of verbal learning, learning has been compared for items generating greater or lesser degrees of arousal increase as shown by EKG and GSR (Lovejoy & Farley, 1970) as well as being compared between Ss differing along personality dimensions such as introversion—extraversion (Gaa & Farley, 1969) and in the presence and absence of arousal-raising stimulation including kinesthetic (Farley & Nason, 1967) and auditory (Haveman & Farley, 1969).

Glickman (1961) has provided an excellent early review of studies on perseverative neural processes. He has pointed out that although various investigators had successfully employed ECS to interfere with memory, they had not attempted to adequately define the temporal features of such interference until 1949, when Duncan took the first step. Duncan trained rats on an avoidance-conditioning problem for 18 days, giving one trial per day. In one group, ECS was induced 20 secs. after the termination of each trial. Additional groups received an ECS 40 seconds, 60 seconds, 4 minutes, 15 minutes, 1 hour, 4 hours, and 14 hours, respectively after each trial. Duncan's results showed that if an hour or more elapsed between the end of the trial and the induction of convulsion, there was no apparent memory loss. But when induced at 15 min. or less, a significant deficit was shown by depressed learning rate of the avoidance response, indicating that the magnitude of the effect decreased as the trial-ECS interval increased leading to a negatively accelerated curve.

Gerard (1955) reported similar findings with hamsters. However, with these Ss ECS administered after 1 hour still had a retarding effect on maze performance.

Thompson and Dean (1955) used four trial-ECS intervals. The group receiving ECS after 10 secs. showed 5% saving; 2 min. later, 35% saving; 1 hour later, 65% saving, and at 4 hours, there was no difference between this group and the control, which did not receive any ECS.

The general conclusion from a number of these studies, seems to be that a single ECS delivered within 15 to 60 minutes following a learning trial, produces deficits in retention, and that an ECS induced immediately after the learning trial effectively obliterates nearly all retention (Glickman, 1961). This point has been further elaborated in an extensive review of reminiscense and consolidation by Farley (1968a). In a more recent study by Bures and Buresova (1963), cited by Farley (1968a), ECS was administered at either 1 minute, 2 hours, or 6 hours, after learning. In each case retention was significantly impaired. Chorover and Schiller (1966), cited by Farley (1968a), in a replication of the above study noted that the effect of ECS administered 2-6 hours after learning was not due to interference with the consolidating trace, but due to an effect upon the locomotor inhibition component of a conditioned emotional response. In an earlier study Chevalier (1965), using a conditioned emotional response found no retrograde amnesia (RA) effects of a single ECS administered beyond 5 minutes following a single learning trial.

Several other studies using drugs or other treatments have demonstrated different temporal gradients of RA (Farley, 1968a). Paré (1961), with 72 albino rats, studied post-learning arousal with drugs. The three hypotheses tested were (1) a depressant drug would inhibit retention of previously learned task, (2) a stimulant would facilitate retention, and (3) that neither facilitation nor inhibition of retention would occur, if the drugs were administered after an hour's interval following task acquisition. One group of rats received 35 mg./kg. of sodium seconal, a second group 30 mg./kg. of caffiene, a third group received a placebo injection of normal saline in dosages of 0.8 cc./kg., and a fourth group was a control group. Each group was divided into three subgroups. The first group received injections 5 seconds after reaching the learning criterion; the second group, 2 minutes; and the third group, 1 hour. Comparisons of drug means revealed that seconal administered Ss made significantly more errors on retention trials when tested after 48 hours, while caffiene-administered animals made significantly fewer errors. He also noted an interaction between the administration of the drug and time. The 5-second and 2-minute groups made significantly more errors on retention trials, whereas the 1 hour group was not different from the control. With caffiene, the 5-second group made significantly fewer errors. The 2-minute and 1-hour groups were not different from the control.

Kincaid (1967) administered ECS 75 seconds after training and metrazol after 5 minutes and found them to be effective in causing RA, persisting undiminished in strength for 21 days. In contrast to the short-term treatments, others have found treatments to be effective when administered at a much longer time. Bickford, et al. (1958) cited by Weiskrantz (1967), noted retrograde amnesia going over a period of weeks. Pearlman, Sharpless, and Jarvik (1961) found metrazol to be effective when administered 4 days post trial. The work of Flexner, Flexner, and Stellar (1963) showed inhibition with puromycin about 3 days later. Alpern and Kimble (1967) reported heat potentiation ether to be effective when administered 24 hours after training and Indokol at four hours post trial.

Commenting upon these studies in general, John (1967) noted that the estimate of the consolidation time not only varies from test to test but varies very much with the nature of the interference. Further, he argues that this disruption may have little to do with the consolidation process but may be a direct result of an insult to the nervous system. However, he suggests that one way out is to inject a relatively small amount of stimulating substance and produce facilitation in learning.

There have been relatively fewer studies using this approach of enhancing the level of perseverative activity so that the trace is activated more often, resulting in greater storage. Of these, Paré's (1961) study has already been cited. Farley (1968a) has discussed a number of such studies, offering support to the consolidation theory. Some of these are Hudspeth (1964), Louttit (1965), and Petrinovich, Bradford, and McGaugh (1965). These studies have used strychnine sulphate administered in relatively low dosages following a learning trial with retention tested 24 hours later. Kimble (1965) cited by John (1967) also noted that small amounts of potassium injected into the lateral ventricle of cats before each learning experience led to improvements in learning as compared to a control group, whereas small amounts of calcium were detrimental. Batten (1967) using human Ss induced arousal by the use of dexedrine (high arousal) or phenobarbitol (low arousal) prior to PA learning. These results were also in the predicted direction. Farley (1968a) has pointed out that studies using strychnine sulphate have not systematically studied the interaction between temporal parameters and stimulation. One study in this direction was reported by McGaugh, Thompson, Westbrook, and Hudspeth (1962). They found facilitation due to drug stimulation up to a learning trial-injection time of 30 minutes.

Another important factor not systematically varied in such studies is the influence of different dosages of drugs, which could have provided useful information regarding optimum level of stimulation. Neither are there studies (except Kincaid, 1967; Alpern & Kimble, 1967; Uehling & Sprinkle, 1968), which have compared two or more different methods of stimulation.

From a review of all these studies, what do we know about the duration of the perseverative process? There does not seem to be a definite answer to this question. However, these studies do indicate that: (1) there is a certain time lapse beyond which the induction of an interfering or a stimulating agent has no effect on memory; (2) within a certain time interval after learning, retention is inversely related to the length of time between the completion of training and the onset of convulsion, the greatest loss occurring when perseveration is disrupted immediately following the learning trial; and (3) it is possible to facilitate long-term retention by the use of stimulants, the optimum time and level of stimulation being largely undetermined.

As regards the duration of the perseveration process, Walker (1967) has stated that it perhaps initiates immediately following the stimulus event This seems to be an inference drawn from the interference studies of consolidation. The results do not seem to be conclusive about the total time taken for the completion of the perseverative activity. It is quite possible that there are large individual differences in this regard.

A few studies have been recently undertaken in the area of verbal learning demonstrating evidence of a relationship between arousal and learning. Obrist (1950) and Thompson & Obrist (1964) measured electroencephalographic (EEG) changes and galvanic skin responses (GSR) during serial learning (SL) of nonsense syllables. Their results indicated that mean GSR was higher during learning than during the control period. Also the GSR and EEG showed a tendency for eacy syllable to produce the highest amount of arousal at about the time it was beginning to be correctly anticipated. Obrist (1962) in another SL experiment found correct anticipation on different days to be linearly related to heart-rate and electrodermographic measures of autonomic activity in two subjects and curvilinearly related in three subjects. Berry (1962) investigated the relation of skin conductance level to recall scores. His data suggested that the relation between level of activation (arousal) and short-term recall followed an inverted "U" relationship. Specifically, he found moderate levels of skin conductance to be related to better recall.

Some of the recent work on arousal and recall has stemmed from the "action decrement" theory of Walker (1958). Walker and Tarte (1963) summarized the major propositions as follows:

> (1) The occurrence of any psychological event, such as an effort to learn an item of a paired-associate list, sets up an active, perseverative trace process which persists for a considerable period of time. (2) The perseverative process has two important dynamic characteristics, (a) permanent memory is laid down in a gradual fashion; (b) during the active period, there is a degree of temporary inhibition of recall; i.e., action decrement (this negative bias against repetition serves to protect the consolidating trace against disruption). (3) High arousal during the associative process will result in a more intensely active trace process. The more intense activity will result in greater ultimate memory, but greater temporary inhibition against recall. (p. 113)

Studies by Farley (1968b), Farley and Lovejoy (1968), Lovejoy and Farley (1970), Manske and Farley (1970), Osborne and Farley (1970) Kleinsmith and Kaplan (1963), Kleinsmith, Kaplan, and Tarte (1963), and Walker and Tarte (1963) have provided support for such a theory. Kleinsmith, Kaplan, and Tarte (1963) employing a PA learning task and only one learning trial, found that 6 min. recall scores were highest for Ss with intermediate conductance levels, but when the interval was increased to one week, recall scores increased montonically. Their interpretations are worth noting—"the inverted 'U' relationship does not necessarily apply to learning . . . any suggestion of an inverted 'U' relationship may be no more than an artifact due to failure to consider the effects of recall intervals employed . . . A person tends to remember vividly those incidents in life which were most traumatic or arousing (positive relationship between arousal and learning)." Kleinsmith and Kaplan (1964) used six nonsense syllables of zero association value as stimulus words and six single digits as responses with only one learning trial. They found that at immediate recall numbers associated with low arousal (measured by GSR deflections), were recalled four times as often as numbers associated with high arousal nonsense syllables. The capacity to recall numbers associated with low arousal stimuli decreased as a function of time in a characteristic forgetting pattern. On the other hand, the capacity to recall numbers associated with high arousal nonsense syllables show a considerable reminiscence effect. After 20 minutes the increase was 100% and after one week, it was 200%.

Walker and Tarte (1963) used homogeneous lists of either high- or low-arousal words (based on a priori rating) and a mixed list of both. The response terms were digits 2-9 and only one trial was given. The interval between learning and recall was 2 minutes, 45 minutes, and 1 week. The immediate recall although in the predicted direction was not significantly different between arousal levels. They then categorized their words as high, medium, and low arousal based upon GSR deflections. High-arousal words show a reminiscence effect, while the low and medium arousal showed the classical forgetting curve. It is interesting to note in their study that medium arousal words had the highest immediate recall at 2 minutes, dropped below the low-arousal words at 45 minutes, and remained more or less the same after 1 week, where they were about the same as the recall of low-arousal items. This point was not discussed by the authors.

Although much of the research cited supports a consolidation theory, little evidence is available of an inverted "U" relationship between arousal and retention as obtained by Berry (1962) and to some extent Berlyne and his associates (1965, 1966).

Except for Farley and Lovejoy (1968), none of the above studies relevant to consolidation has used any experimental techniques of manipulating arousal. Such studies are perhaps more meaningful in establishing a cause and effect relationship between arousal and retention. A variety of methods have been employed by investigators to induce arousal, such as drugs (already discussed), ego-orientation instructions, delayed auditory feedback, and white noise.

Alper (1948) used "ego-oriented" instructions with one group and "task-oriented" instructions with another group. The task was PA learning. She found "ego-oriented" Ss not only recalled significantly more new items on Day 2 than on Day 1, but also recalled on Day 2 significantly more of the same items they had recalled on Day 1 than did the "task-oriented" Ss.

There have been a number of studies using delayed auditory feedback as a means of arousal. Among these are studies by Harper and King (1967), King (1963), King and Dodge (1965), King and Walker (1965), and King and Wolf (1965). They found that under a delayed auditory feedback of 0.2 to 0.8 seconds immediate recall was significantly poorer than that of controls. However, on a 4-hour test there was greater retention relative to the initial amount of material recalled, in comparison to the control group.

Among the more recent studies experimentally manipulating arousal the most relevant to the present discussion have been those using white noise as a means of arousal-induction. Berlyne and Lewis (1963) have reported that white noise raised one index of arousal, skin conductance, and kept it raised for at least 10-15 min. Podvoll and Goodman (1967) have shown that white noise lead to increases in multiple-unit activity in the reticular activity system. It should be pointed out that a detailed relationship between physiological activation and white noise is not entirely established (see Gibson & Hall, 1966; Costello & Hall, 1967; Lovejoy & Farley, 1970). However, white noise has certain advantages, in that the E can switch it on and off at his will (Berlyne, 1968) and can vary the intensity of white noise to induce differential arousal levels.

Almost all studies using white noise have been concerned with arousal during learning [except Farley & Lovejoy (1968)]. Berlyne, et al. (1965) reported using two levels of noise and a PA task with three training trials. They found that Ss subjected to 72 db. white noise during training and testing had poorer recall than the no white noise group when tested after 24 hours. The 58 db. group, although scoring better, was not significantly different from the control condition. In another experiment reported in the same paper, five levels of white noise were used, 35 db. to 75 db. in steps of 10 dbs., with five independent groups. The findings may be summarized as follows: (1) on the training day, significantly less recall was obtained with white noise than without it, while on the test day items learned under white noise the day before were recalled significantly more often than others, (2) no significant effect of white noise during the test trial was obtained, (3) variations in intensity of white noise had no significant influence, and (4) there was some hint of curvilinearity with maximum effects at about 65 dbs.

In a later study Berlyne, et al. (1966), manipulated the timing of arousal with one intensity of white noise (75 db.). The task was PA learning with three training trials being given. Four conditions were employed with variations in the onset and termination of white noise. White noise was presented: (1) during the presentation of stimulus (4 seconds) alone and stimulus and response term together (2 seconds), (2) during the interval between items (6 seconds), (3) during the entire period of 10 seconds (the presentation of the stimulus, the stimulus and response terms, and the interval), and (4) no white noise condition. Working with the action-decrement notion, Berlyne, et al., expected that white noise given after the response had been completed would aid long-term recall.

This was based on the notion that the principle role of arousal is in the consolidation of memory traces during a period of perseveration, involving reverberatory circuits following the response. The results indicated that presentation of white noise after a response made no significant difference on a 24-hour test. Analysis of variance indicated that recall was significantly better in conditions with white noise than without it. But there was no significant difference between the noise conditions themselves. On a second experiment using the same conditions, it was found on a short-term memory test taken immediately after the training trial that recall under different arousal conditions was not significantly different nor was there evidence of interaction. However, when the results of the two experiments were compared, they noted that the mean recall scores over training Trials 2 and 3 were significantly higher than Experiment one, which was contradictory to these earlier results (Berlyne, et al., 1965) and to the Walker studies. Berlyne, et al., disfavored the perseveration hypotheses in this study on the basis that white noise after the response had no significant effect.

Considering the results of both the 1965 and 1966 experiments, Berlyne, et al. (1966), concluded that in some experiments immediate recall following high-arousal learning was found to be worse while in others increases in arousal have not always been detrimental to short-term recall, but may in some conditions improve it. Moderate auditory stimulation, according to these authors, has been found to favor immediate recall in PA and serial learning. They conclude that it is quite likely that there is an optimum degree of arousal for immediate recall, with the location of this optimum varying with the nature of the material and the interval between learning and recall (see also Berlyne, 1968).

The Berlyne, et al., studies, especially the later one (1966), are not strictly comparable to the Walker studies from the point of view of the procedures and parameters being used. Berlyne, et al., used three training trials, while Walker and the Michigan group used only one learning trial. Hence in the Berlyne, et al., studies the results may have been confounded by rehearsal effects, especially since the interval between two PAs was filled with a blank slide. The most serious objection to the later study is the fact that Berlyne, et al., contend that white noise raises skin conductance, and keeps it raised for 10-15 minutes. Considering the design of their study, one finds that one group received white noise for 6 seconds, during the appearance of the stimulus-term alone (4 seconds) and appearance of stimulus term and response term together (2 seconds). Accordingly, when white noise was delivered for the first 6 seconds, it might be argued that the S should remain in a high state of arousal for the next 10-15 minutes and this should influence the learning of the later material. The same logic could be applied to Condition 2, where white noise was given at the appearance of the response term (6 seconds). This in fact should make the two groups equivalent from the point of view of arousal and their recall scores should not therefore be very different, with the small differences attributable to chance. The third condition was only different in that white noise was given continuously.

Haveman and Farley (1969) did not obtain significantly better long-term recall with white noise presented during learning of PA and SL tasks. They used 75 db. intensity. However in a third experiment with free learning, the prediction of better long-term recall was supported. The finding that arousal did not have a detrimental effect on immediate recall was substantiated in all the three experiments. They interpreted these results along the lines of Berlyne, et al. (1965), that effects of arousal are dependent on the nature of the material to be processed.

Recently Uehling and Sprinkle (1968) manipulated arousal just prior to retention tests for three minutes. They had three conditions: (1) low arousal in which Ss were asked to relax, (2) muscle tension arousal group in which the Ss were asked to exercise with muscle tensors, and (3) white noise group, in which white noise of 80 db. with irregular intervals was delivered with the help of a tape recorder. For each condition, there were three separate groups for three retention intervals. The results indicated that on immediate recall there was no significant difference between the three groups. After 24 hours, however, the white noise group differed significantly from both the muscle tension and low arousal groups, which did not differ significantly from each other. After 1 week the white noise condition differed significantly from the low-arousal group but not the muscle tension group. Although the authors interpreted their results within the general framework of arousal, it could be seen that arousal in this study was not detrimental to immediate recall. The other phase of the experiment employing the 24-hours and 1-week retention interval cannot be interpreted in terms of consolidation since it is more concerned with trace arousal rather than trace formation.

The only human learning study which has systematically varied temporal gradients of arousal during the consolidation period is that of Farley and Lovejoy (1968). Six nonsense syllable—familiar word pairs constituted the PA learning task, with two learning trials being administered. They delivered white noise (75 db.) to three different groups, between 0-3 minutes, and 6-9 minutes, respectively, following the last learning trial. A control group received no white noise. The results indicated a significant main effect of arousal on long-term recall in the predicted direction. However, over a 12-minute retention test no difference was found between no white noise and white noise conditions. Comparing the results of 12 minutes and 24-hour retention tests it was found the control group's recall decreased by almost 30%. Recall decreased by 14% and 8% in the case of the 0-3 minute, and 6-9 minute groups, respectively, while in condition 3-6 minutes there was a marked reminiscence effect by almost 20%, quite contrary to their expectation of decreasing recall from condition 0-3 minutes to 3-6 minutes.

An overview of the literature suggests that there are two major view points concerning arousal and retention. One approach strongly favors a positive relationship between arousal and retention, such that high arousal is detrimental to immediate recall and facilitative of long-term recall. On the other hand, another view strongly supports an inverted "U" relationship between arousal and retention. However, no definite conclusions can be drawn regarding the optimal level of arousal and the optimum time of arousal from the studies reported to date. As has been seen most studies with human Ss have been concerned with arousal during learning, with very little attention being paid to post-learning arousal manipulation. The study of Farley and Lovejoy (1968) was of the latter type and served as a basis for the present investigation, with certain modifications. Farley and Lovejoy (1968) worked with two levels of noise, i.e., 75 db. and a no-noise condition, and provided two training trials on nonsense syllable-word pairs. It is possible that their results were confounded with rehearsal effects. Also their design allowed inferences about time but not the intensity of arousal.

With these considerations, the present study was designed to examine the influence of experimentally induced arousal after learning, manipulating both the time and intensity of arousal, on long-term retention. Only long-term retention was studied, thus eliminating short-term effects so as to ensure that we were dealing with durable learning effects and not merely transient performance effects (Berlyne, 1967).

Two levels of white noise manipulation (75 db. and 90 dbs. SPL, reference level being .0002 dynes/cm.[2]) were chosen with a no-noise condition constituting the control group. The latter group did not represent entirely a "no-noise" condition since the ambient noise level was 56 dbs. SPL in the testing room with two people inside. Hence, the "no-noise" condition is used in the sense that no white noise was administered to this group. This also constituted the low-arousal condition in the study. The 75 db. SPL was chosen so as to obtain a moderate level of arousal (Chase & Grah[illegible] 1967) and also due to the fact that 75 [illegible] intensity has been used in earlier studies of Berlyne (1965, 1966), Haveman and Farley (1969), and Farley and Lovejoy (1968). The 90 dbs. noise level was chosen so as to obtain a high-arousal condition. Gibson and Hall (1966) reported that stimuli between 85 db. and 100 db. were judged reliably as being distractive and noxious and presumably resulting in a higher level of physiological activation. To keep noise conditions below damaging limits, no stimulus higher than 90 db. was chosen (Harris, 1957). Yet another consideration in the study was the form of noise. Earlier studies had used a continuous form of noise. Since the noise was to be delivered for a total of 3 minutes in the present study [the duration employed by Farley & Lovejoy (1968)] it was considered that a continuous form would result in fatigue or habituation effects. Therefore the noise was shaped and pulsed through an electronic switch before delivery to the Ss' earphones.

There were three temporal intervals of post-learning arousal manipulation chosen in this study—0-3 minutes, 3-6 minutes, and 6-9 minutes; these parameters were based on the Farley and Lovejoy (1968) study. The design of the study could be diagrammatically represented in Figure 1.

In brief, the experiment was designed to study:

(1) The effects of three levels of arousal (0, 75 db., and 90 db. SPL) induced by white noise after a PA learning trial on long-term retention (24 hours). On the basis of earlier studies, it was expected that the noise conditions would facilitate long-term retention as compared to the no-noise condition.

(2) The effects on long-term retention of inducing arousal by white noise at three temporal intervals, 0-3 minutes, 3-6 minutes, and 6-9 minutes, following a learning trial.

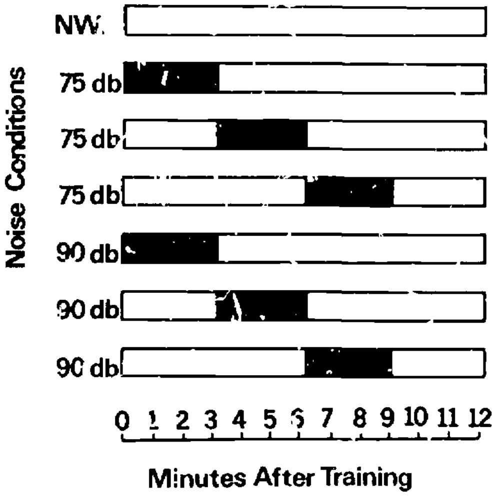

Fig. 1: Experimental Conditions Representing Intensity and Temporal Parameters of Arousal

(3) If there are any relationships between the level of arousal (noise intensity) and timing of arousal in influencing long-term retention (24 hours).

Another variable of interest included in the experiment on an exploratory basis was the mediation latency (Runquist & Farley, 1964) on each of the PAs following recall. There were two considerations for including this variable in the study: (1) to determine if there was a relationship between mediation latency and recall score and (2) whether arousal intensity and the timing of arousal influenced mediation speed. Runquist and Farley (1964) have reported that the latency of forming a natural language mediator between stimulus and response pairs in PA learning is significantly associated with rate of acquisition in the PA task. This has suggested that such often complex (covert) mediators and mnemonics are employed in PA learning and that more than simple S-R association can be involved. The present study explored whether temporal and intensity aspects of arousal manipulations would have an effect on mediation as measured by the Runquist and Farley "mediation speed" test.

II
METHOD

SUBJECTS

The Ss were 56 female students drawn from different undergraduate courses in Educational Psychology and Art Education. Students taking Educational Psychology were given one hour credit for their participation. Nevertheless, their participation was voluntary. Any such Ss who were involved in other learning experiments were not included in the study. The participation of Art Education students was purely voluntary. Ss had to be taken from a department other than Educational Psychology primarily because a number of the latter Ss had already been involved in other learning experiments prior to the present study.

Only those Ss who had had no ear or hearing problems were asked to participate.

MATERIALS AND APPARATUS

Learning Task

Since the experiment where the learning task is concerned was designed along the lines of Kleinsmith and Kaplan (1964) study, these authors' learning task was used. Six PAs, each consisting of a stimulus term and single-digit response term were presented during the learning trial. The stimulus words alone were used during the recall period. The stimulus words were CVC nonsense syllables of zero percent association value (to obtain "random" arousal effects); namely, CEF, QAP, TOV, JEX, LAJ, and DAX. The response terms were single digits from 2 to 7 respectively. The stimuli and the stimulus-response pairs were presented on 2" x 2" slides. Two 2" x 2" color slides each containing five colored spots arranged horizontally in two rows (red, green, orange, brown, yellow, and blue were randomly used on these slides), were inserted between the PAs to separate the arousal effects of one stimulus from the next (Kleinsmith & Kaplan, 1964).

Interpolated Task

Two mazes were used as the interpolated task following the completion of the learning trial. Some considerations in selecting the mazes as a task were

(1) the task shouldn't be uninteresting;

(2) should be simple and involve a minimum of thinking or mental activity, so that there is minimum of interference from such processes during the consolidation period [Posner and Rossman (1965) and Weiner (1967) have demonstrated that retention is greatly reduced as the difficulty of an interpolated task increases.]; and

(3) should not be too arousing or tiring or related to the learning task.

Farley and Lovejoy (1968) had used 17 random polygons and had instructed Ss to rate them on a 1 to 7 scale on dimensions of interestingness, complexity, pleasingness, dullness, unusualness, and dislike. Mazes were preferred to the polygons because it was suspected that they might induce arousal and additionally that they might induce arousal and additionally that rating on a 1 to 7 scale would be working with digits as used in the learning task [Farley and Lovejoy did not employ digits in their learning task]. Another consideration was that the task should be E paced and not S paced because S pacing may involve some Ss working very rapidly and others very slowly, thus inducing differential arousal effects depending upon what they understood the purpose of the task to be, as well as reflecting such individual difference factors as personal tempo (Rethlingshafer, 1963). Hence, each S worked on each maze for 7.5 seconds. The timing was determined from a pilot study with three Ss who considered 5 seconds to be too short and 10 seconds too long to satisfactorily complete a maze.

The time interval for working on the mazes was controlled by a programmed light flash (1.5 v., .075 A) through the use of a Cousino Synco-Repeater Model SR-7341. The light bulb was fixed at a convenient distance and height for the S, and was covered by a cap during the learning trial. The Cousino was kept outside the testing chamber to minimize noise effects.

Testing Conditions

The slides for learning and recall were projected from outside an Industrial Acoustics Company Model 1202A acoustic chamber to a projector screen covering one of the chamber's windows, thus effecting back projection presentation. [The chamber had a measured ambient noise level of 56 dbs. (reference level of .002 dynes/cm.^{2} SPL) assessed with Bruel and Kjaer equipment described below, with two persons in the booth.] The chamber was lighted with a 60-watt incandescent bulb turned away from the S's face, thus providing one foot candle luminance at S's face as measured by a General Electric DP-9 lightmeter.

Arousal Equipment

White noise was generated by a Grason-Stadler Model 901B white noise generator. The signal from the generator was shaped and pulsed (125 msecs. on and 125 msecs. off, with a rise and decay time of 25 msecs.) by a Grason-Standler Model 829E electronic switch, transmitted through a General Radio Model 1450 alternator and finally delivered to S via TDH 39 earphones mounted in MX 41/A-R cushions. Pulsed noise was preferred to a continuous noise condition to avoid fatigue and habituating effects.

Prior to running the experiment the acoustic output of the system was calibrated to 90 dbs. and 75 dbs. (reference level of .0002 dynes/cm.^{2} SPL) with Bruel and Kjaer apparatus consisting of the following components: artificial ear H152, 6cc. coupler NBS - 9A, condensor microphone 1432, cathode follower 2613, and audio-frequency spectrometer 2112. The output of the system was checked by monitoring the voltage across the terminals of the earphones and the values of tolerance were found to be between ± 0.5 db.

All the apparatus were outside the sound proof booth and controlled with a switch inside.

Audiometric Screening Equipment

Prior to participation in the experiment each S's hearing was screened bilaterally at 15 dbs. International Standards Organizational (ISO) with a Beltone Model 15c audiometer on the following frequencies: 250, 500, 1000, 2000, 4000, and 6000 Hz. This was done to insure that only Ss with normal hearing were included in the experiment. An intercom was used at the time of screening since the experimenter was outside the testing booth.

Miscellaneous Equipment

The following equipment was used: Stopwatch, GSR transducer and connecting cord, 3" x 5" cards each containing one stimulus and response pair for use in the mediation test following recall, and a projection screen.

Design

Ss were randomly assigned to one of the seven conditions with eight Ss per cell (See Figure 1.). To correct for serial order effects six different training lists were generated so that each of the six PAs appeared once in each ordinal position in the list (Fisher & Yates, 1938). Since there were eight Ss, two of the lists were randomly picked from out of the six and were used twice. The Ss were randomly assigned to lists and conditions using the block randomization method. The lists were similarly assigned for the recall and mediation trials but with a restriction that the same S did not get the same list order for all the three trials.

Procedure

The windows of the test chamber were covered to eliminate any visual distractions The Ss were seated comfortably in a padded chair located in the booth.

The Ss were first told that the major purpose of the experiment was to take a series of physiological measures while they were performing various tasks. These instructions were given to divert the attention of the S from the main (learning) task, thus preventing rehearsal and to disguise the nature of the task to be given 24 hours later [the latter was ostensibly to give an estimate of any physiological changes over 24 hours]. The Ss were then screened for normal hearing on the following frequencies: 250, 500, 1000, 2000, 4000, and 6000 Hz. The Ss indicated over the intercom whenever they heard a tone. The criterion of rejection for abnormal hearing was set at a failure to detect tones at two or more frequencies (Newby, 1964). Following audiometric screening the GSR transducer was attached to Ss' nonpreferred hand with a back-of-hand to palmar placement. She was informed that GSR, a harmless, simple physiological measure, would be automatically recorded outside the chamber. No skin preparation was undertaken, nor were the sponge electrodes impregnated with electrode jelly, as real GSR recordings were not in fact taken.

The learning phase involved presentation of the PAs; during the learning trial, each stimulus term appeared alone for 5 seconds, followed by the stimulus and response term for another 5 seconds. The PA slides were followed by two colored slides for 5 seconds each. The Ss were, however, given a 10-second familiarization period with the color slides prior to the learning trial in order to reduce any arousal effects that might be attributable to the presentation of these slides during learning. Also during this period, E verbally labelled the colors for S and ascertained that S experienced no confusion or difficulty in discriminating them. Two color slides then preceded the first PA so that the S could "settle down" before the PAs were presented. The Ss were instructed to "concentrate carefully on both the colors and the nonsense syllable number-pairs and to call them out loud," but to avoid rehearsal they were not specifically told that they would be tested for recall.

After the learning trial, all Ss worked on a set of mazes for 12 minutes. The instructions for the mazes were given immediately after the instructions for the learning trial. The Ss were also familiarized with both the mazes and the light flash signal at the time of giving instructions, for the same reason mentioned earlier, and were instructed to start working on the mazes immediately after the learning trial.

During the consolidation period, the experimental Ss (six conditions, n = 8), received white noise through earphones. There were two levels of noise intensity—75 dbs. and 90 dbs.—delivered during 0-3 minutes, 3-6 minutes and 6-9 minutes following a single learning trial. Subjects were told a few seconds before the presentation of white noise that they would hear a sound in their ears which would not hurt them. The Ss wore earphones only during the noise interval to avoid anxiety or arousal from further anticipation of receiving noise. The Ss continued to work on the mazes throughout the 12-minute period, including the period of noise presentation. All the Ss were required to work on the mazes for 12 minutes for two main reasons. First, the condition which received noise during 6-9 minutes would receive at least 3 minutes of maze performance after the induction of arousal so as to avoid any special interference immediately after the presentation of the arousal stimulus. Second, all Ss worked on the mazes for the same amount of time in order to insure constancy among conditions (See Figure 1). The control group or the no white noise condition (NWN) did not wear earphones at any time and simply worked on the mazes for 12 minutes. This was done to avoid any anxiety due to wearing earphones since noise was not to be presented and it would have been difficult to convince Ss to wear them without reason.

The Ss were then requested to come next day at the same time for another set of physiological measures.

During the recall session, the Ss were again instructed that the purpose of the experiment was to take physiological measures. To insure constancy of conditions the GSR tranducers were again used. Stimulus words alone were presented for 5 seconds each and the Ss were instructed to recall the correct number and to guess if uncertain. The correct numbers were not repeated. Color slides were used as before as an interpolated task.

Immediately following the recall test Ss were tested for mediation latency on the same PAs which were presented by E on a 3" x 5" index card. Ss were instructed to write on a response sheet the way they might remember the combination of the syllable and the number, that is, the way she might associate the syllab'e and number within each pair. An example was given to make the task clear. The Ss were timed by E to the nearest second on the time taken to form a "mediator" for each PA.

The Ss were then once again screened for hearing, to emphasize the physiological nature of the experiment, and requested not to mention the experiment to their fellow students.

III

RESULTS

RECALL ANALYSIS

In Table 1 is located the mean number of correct responses on the 24-hour retention test for the different conditions of intensity and timing of arousal. The figures in parentheses indicate the mean percentages.

The same results are presented in Figure 2, where the mean percentage of recall scores have been plotted against intensity and time of arousal. Table 1 clearly reveals that mean recall was higher for 75 dbs. of white noise administered between 6-9 minutes after the last learning trial when compared with the other conditions. There was no difference in mean recall between the control group and 90 dbs. group given noise between 6-9 minutes. Mean recall scores were the same for 75 dbs. and 90 dbs. noise given between 0-3 minutes. The middle interval of 3-6 minutes for both 90 dbs. and 75 dbs. showed the lowest mean recall with the 75 dbs. condition demonstrating a somewhat higher recall than the 90 db. condition. Mean percent recall for different intensities of white noise, irrespective of temporal parameters, and mean percent recall for different temporal parameters, regardless of intensity, are shown in Figures 3 and 4, respectively. From Figure 3 it can be seen that an inverted "U" function has been suggested relating arousal level to recall, such that best recall is associated with middle levels of arousal

Table 1

Mean Number of Correct Responses Under Different Conditions of Intensity and Timing of Arousal

Intensity of Arousal	Timing of Arousal 0-3 min.	3-6 min.	6-9 min.	Combined Mean
No White Noise				
No White Noise	0.88 (14.58%)			0.88 (14.58%)
75 db.	1.13 (18.75%)	0.75 (12.50%)	1.63 (27.08%)	1.17 (19.44%)
90 db.	1.13 (18.75%)	0.50 (8.33%)	0.88 (14.58%)	0.83 (13.89%)
Combined Mean	1.13* (18.75%)	0.63 (10.42%)	1.25 (20.83%)	

*This includes only the scores for 75 db. and 90 db. groups and not the control group.

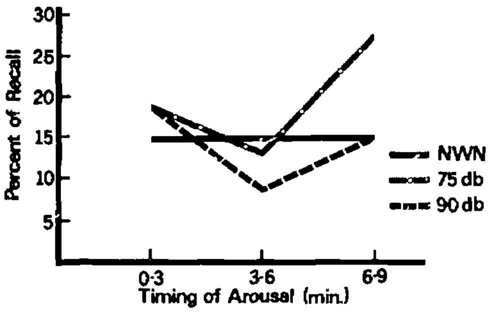

Fig. 2: Mean Percent Recall Under Different Conditions of Intensity and Timing of Arousal

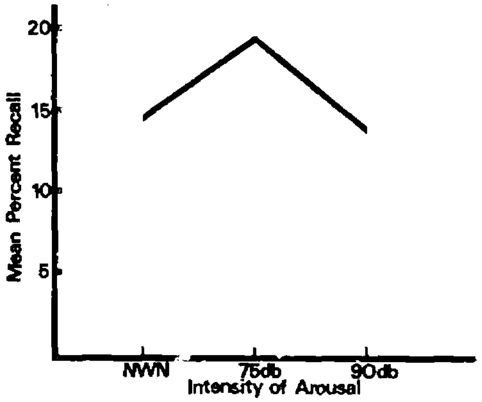

Fig. 3: Mean Percent Recall for Different Intensities of Arousal

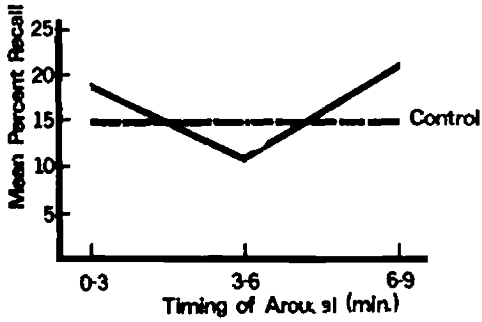

Fig. 4: Mean Percent Recall as a Function of the Timing of Arousal

(75 db.). Figure 4 suggests that a "U"-shaped relationship of recall to the timing of arousal has been obtained. The mean percent recall for the 0-3 minute condition is higher than the NWN group but somewhat lower than the 6-9 minute condition. The 3-6 minute condition demonstrated lower mean percent recall when compared to the other three conditions.

The data summarized above were subjected to statistical analysis using the procedure of computing "t" ratios for specific contrasts (Hays, 1966). The various linear contrasts were planned by examining the data. No restrictions were followed about the orthogonality of contrasts, as it was believed that running non-orthogonal comparisons, although possibly providing some overlapping information, would make interpretation more clear as to the locus of effects.

Table 2 presents some of the contrasts examined and their obtained "t" values. Thus, for example, the contrast 1 is concerned with testing whether the mean of condition NWN is different from the average of the means of all other conditions, and so on. An examination of Table 2 reveals several interesting things. Contrast 1, between the means of the no-white noise condition and the noise conditions, is not significant and neither are combined means of 75 db. intensity different from the combined mean of 90 db. (Contrast 2). Contrast 3, comparing the means of 75 db. noise level with the combined means of no-white noise and 90 db., is also not significant. These contrasts indicate that the intensity of arousal <u>per se</u> has no effect on long-term retention.

The other contrasts evaluate the effects of temporal parameters. Contrast 4 shows that 75 db. administered between 6-9 minutes is significantly different from a combined mean of all the other groups, indicating superior recall. However, on the former condition this effect seems to disappear when the mean of 90 db. 6-9 minutes, is added in (Contrast 5). The sixth contrast between the mean recall for 75 db., 6-9 minutes, and the control group is not significant ($p > .05$). Contrasts 7 and 8 between the means of 75 db. delivered 6-9 minutes, and 75 db., 3-6 minutes, and 90 db., 3-6 minutes, respectively, show significant differences. Contrast 9 between the mean of 75 db., 6-9 minutes, and 90 db., 6-9 minutes, is not significant at $p > .05$ level, and Contrast 10 between 75 db., 6-9 minutes, vs. 75 db., 0-3 minutes, is not significant ($p > .05$). Contrasts 11 and 12 show no significant differences between the control group and 75 db., 0-3 minutes, or 90 db., 3-6 minutes, groups ($p > .05$).

Table 2

Linear Contrasts Between Means and Their Obtained "t" Values
(Long Term Retention)

Contrast Number	Intensity	NWN		75 db.			90 db.		Obtained "t"	p <
	Timing	0	0-3	3-6	6-9	0-3	3-6	6-9		
	Means	0.88	1.13	0.75	1.63	1.13	0.50	0.88		
1		-6	1	1	1	1	1	1	1.75	.10
2		0	1	1	1	-1	-1	-1	1.50	.20
3		-1/4	1/3	1/3	1/3	-1/4	-1/4	-1/4	1.56	.20
4		-1	-1	-1	6	-1	-1	-1	2.56	.02
5		-1/5	-1/5	-1/5	1/2	-1/5	-1/5	1/2	1.66	.10
6		-1	0	0	1	0	0	0	1.95	.10
7		0	0	-1	1	0	0	0	2.29	.05
8		0	0	0	1	0	-1	0	2.95	.01
9		0	0	0	1	0	0	-1	1.95	.10
10		0	-1	0	1	0	0	0	1.30	.20
11		-1	1	0	0	0	0	0	0.65	.50
12		1	0	0	0	0	-1	0	0.99	.50
13		0	1	-1	0	1	-1	0	1.80	.10
14		0	-1	0	1	-1	0	1	0.46	.80
15		0	0	-1	1	0	-1	1	2.32	.05
16		0	1	-2	1	1	-2	1	2.41	.02

Contrasts 13, 14, 15, and 16 are also concerned with temporal parameters but testing their combined means. Contrasts 13 and 14 indicate that arousal induced between 0-3 minutes is not different from 3-6 minutes or 6-9 minutes individually. The combined means of 0-3 minutes condition and 6-9 minutes, regardless of intensity, are significantly different from 3-6 minutes condition showing poor recall in the latter (Contrast 16). The combined mean of 3-6 minutes is significantly different from 6-9 minutes, indicating superior recall in the 6-9 minutes condition (Contrast 15).

Since the Ss were drawn from two departments (Educational Psychology and Art Departments) and that students from the former got credits for participation and the latter volunteered, possible confounding of results may have occurred although Ss were randomly assigned to the treatments. This was analyzed by testing the difference between the means of the two groups. The means of Educational Psychology students (N = 24) and Art Department students (N = 32), were 0.8750 and 1.0625 respectively. The "t" value obtained (t = .8704) for uncorrelated groups was not significant ($p > .05$, two tailed).

Serial Effects

Analysis was undertaken to find out if there were any effects on recall due to the serial position of words during learning. Frequency of correct responses were tabulated against each ordinal position irrespective of the PAs. In Figure 5, percent recall was plotted against serial position during learning. A "Q" computed using Cochran's test for repeated observations (Hayes, 1966), on these data was not significant ($Q = 1.35$, $X^2 > .05$). Also, each PA was separately taken and a frequency distribution was made against different serial positions in which it appeared. Of the six X^2 associated with the six PAs, none were significant ($p > .05$).

Since no differential effects of serial position on recall were obtained, no further analysis with the first word removed was undertaken (See Lovejoy and Farley, 1970).

Error Analysis

An error analysis was undertaken that included errors of omission and commission, with the latter being broken down into intra-

Fig. 5: Mean Percent Recall as a Function of the Serial Position of PAs During Learning

list and extralist errors. Separate analyses of the three error types were undertaken using analysis of variance. No significant relationships between experimental conditions and error type were obtained. No analysis of total errors was undertaken as these were perfectly correlated with recall scores which had already been analyzed (see Table 1).

Mediation Speed Analysis

Mean mediation latency time was computed for each S over all PAs and the overall mean for each condition was determined. Means for different conditions are shown in Table 3.

Table 3

Mean Mediation Latencies According to Different Conditions

Intensity of Arousal	Timing of Arousal 0-3	3-6	6-9	Combined Mean
NWN	31.06			31.06
75 db.	22.40	33.46	19.96	25.27
90 db.	26.86	28.15	19.67	24.89
	24.36*	30.80	19.81	

*Does not include NWN data.

Table 3 indicates that 6-9 minute groups for both levels of noise took the shortest time to form the mediators. The combined mean for different temporal parameters were also computed. It is interesting to note that Ss in the 3-6 minutes condition not only showed the poorest recall but also took the longest time to form the mediators. Thus, there is a similar pattern of relationship between mediation latency scores and recall scores for different conditions of temporal parameters (see Figure 6). However, this does not hold true for the noise levels.

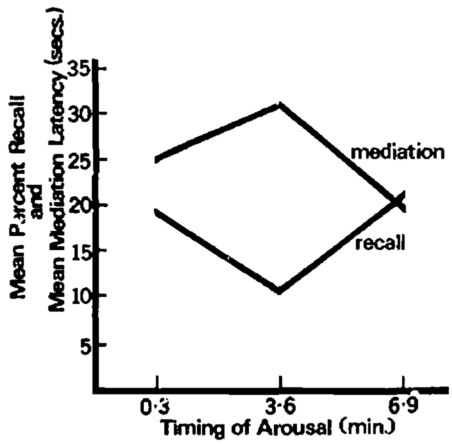

Fig. 6: Relationship Between Mediation Latency and Recall for Different Temporal Intervals

Further analysis was performed using the procedure of calculating "t" ratios for specific contrasts. The contrasts tested were the same as in Table 2 since it was intended to know the extent of similarity and differences between the recall data and the mediation latency data. Table 4 presents the linear contrasts and the obtained "t" values.

Similar to the results obtained for recall data, there is no difference between the white noise and no white noise conditions—(Contrast 1). Also there are no differences between the two conditions of white noise (Contrast 2). Hence, mediation latency does not seem to be a function of intensity of arousal in this study.

Temporal parameters on the other hand do seem to have an effect on mediation latency. The combined mean of 6-9 minutes at both levels of noise is significantly different from a combined mean of all other groups (Contrast 5). As in the recall analysis presented in Table 2, the combined mean for 6-9 minutes is significantly different from a combined mean of 3-6 minutes, but not from 0-3 minutes (Contrast 14 and 13). Also the combined mean of

Table 4

Linear Contrasts Between Means and Their Obtained "t" Values
(Mediation Latency)

Contrast Number	Intensity Timing Means	NWN 0 31.06	75 db. 0-3 22.40	75 db. 3-6 33.46	75 db. 6-9 19.96	90 db. 0-3 26.86	90 db. 3-6 28.15	90 db. 6-9 19.67	Obtained "t"	p <
1		-6	1	1	1	1	1	1	1.28	.20
2		0	1	1	1	-1	-1	-1	0.11	N.S.
3		-1/4	1/3	1/3	1/3	-1/4	-1/4	-1/4	0.35	.80
4		1	1	1	-6	1	1	1	1.41	.20
5		1/5	1/5	1/5	-1/2	1/5	1/5	-1/2	2.38	.05
6		1	0	0	-1	0	0	0	1.83	.10
7		0	0	1	-1	0	0	0	2.22	.05
8		0	0	0	-1	0	1	0	1.35	.20
9		0	1	0	-1	0	0	0	.40	.80
10		1	-1	0	0	0	0	0	1.42	.20
11		1	0	0	0	0	-1	0	0.48	.80
12		0	-1	1	0	1	-1	0	1.44	.20
13		0	1	0	-1	1	0	-1	1.12	.50
14		0	0	1	-1	0	1	-1	2.55	.02
15		0	-1	2	-1	-1	-2	-1	2.00	.05

0-3 minutes and 6-9 minutes for both levels of noise is significantly different from 3-6 minutes (Contrast 15).

In order to determine the relationship between recall and mediation latency, a Pearson product moment correlation was computed between the recall scores and the mean mediation time of each S over all six PAs. The correlation was -.237, which was significantly different from zero at $p < .05$ (N = 56). The percentage of shared variance between the two variables was about 6%. A "t" test between the mediation latencies for recalled items and not recalled items yielded a value of -0.4994, which is nonsignificant.

The data were further analyzed to find out if there were any differences in relationship between mediation time and recall under each sub-condition. Pearson "r"s computed between recall and mean mediation latencies are reported in Table 5.

None of the correlations except that of 90 db., 6-9 minutes group was significantly different from zero at $p < .05$, indicating that Ss in this sub-condition with higher recall scores took shorter time to form mediators. The percent of variance shared by the two variables in this sub-condition is almost 54%.

The data were also analyzed to see if Ss took less time for the last three PAs, presented during the mediation test, as compared with the first three PAs. A "t" test performed on the mean mediation time of the first three PAs and the last three PAs yielded a value of -0.3078 which is clearly nonsignificant. To find out the level of difficulty of each PA, mean mediation latencies were computed over all Ss and plotted in Figure 7. It can be noted that the differences are very slight between the mean mediation latencies reported for the six PAs.

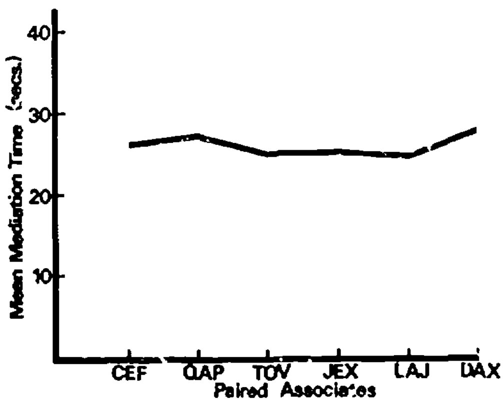

Fig. 7: Mean Mediation Latency for each PA

Table 5

Pearson Product Moment Correlation Between Mean Mediation Latencies and Recall Scores for each Condition (N = 8 for each Group)

Intensity	NWN		75 db.			90 db.	
Timing	0	0-3	3-6	6-9	0-3	3-6	6-9
"r"	-.197	.433	-.595	-.058	-.132	.123	-.735*

*Significant - $p < .05$.

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IV
DISCUSSION

RECALL ANALYSIS

The results tend to indicate that a moderate level of arousal induced between 6-9 minutes is conducive to the consolidation process, resulting in superior long-term recall. These findings are in contradiction with both the Farley and Lovejoy (1968) study which obtained a reminiscence effect due to arousal between 3-6 minutes and the expectation from the ECS and drug studies of decreasing recall as a function of time between learning and ECS or drug administration. However, these results have to be interpreted with some caution, since the contrast between 75 db., 6-9 minutes and the control group fail to reach the .05 level of significance. The effects might not have shown up in these cases because the power of the test may be low (the sample size in each cell being small) or possibly due to a "floor effect," which is evident from the fact of generally low recall scores. This suggests that the learning task was difficult, which prevented Ss from producing an adequate amount of learning to test the hypothesis under consideration (Runquist, 1966). These results are consistent with Osborne and Farley (1970) who used the same PA learning task and reported relatively low levels of performance.

The data do seem to suggest an inverted "U" relationship between intensity of arousal and long-term recall, as seen in Figure 2, with recall being superior at moderate levels of arousal as compared with low and high levels of arousal. This is consistent with studies of Berlyne, et al. (1965, 1966), but contradictory to the results obtained by the Michigan group. These results are not conclusive particularly since there was no significant difference between the combined mean of moderate level of arousal (75 db.) and the high level of arousal groups (90 db., Contrast 2, in Table 2).

Regarding temporal parameters of arousal, comparisons between the combined means of recall scores for the three intervals were made. (Contrasts 13, 14, and 15 in Table 2). Arousal induced between 6-9 minutes produced significantly different recall when compared with 3-6 minutes. The contrast between the 0-3 and 6-9 minute groups was not significant nor was that between 0-3 minutes and 3-6 minutes.

The present results are difficult to interpret from available literature. Considering notions proposed by Walker (1966, 1967), we could divide the course of memory trace formation into three functionally different periods of short-term memory, dynamic trace period, and structural trace period or long-term memory (see Figure 8).

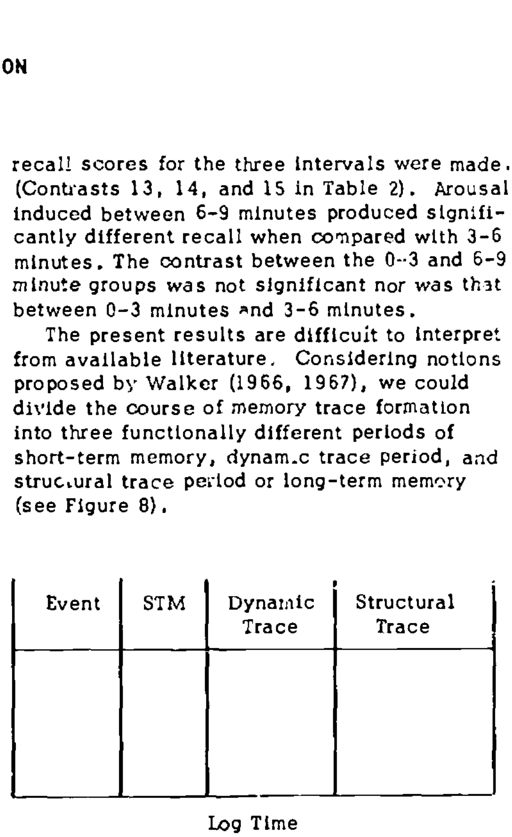

Figure 8: Diagram Showing Three Functionally Different Periods of the Memory Trace (Walker, 1967, p. 189).

The time limits of these phases are not determined. If such a sequence could be assumed then one might hypothesize that a moderate intensity of arousal during the structural trace period (here hypothesized to be during the 6-9 minute period) is conducive to the consolidation process, while any manipulation during the dynamic trace period (here hypothesized to be during the 3-6 minute period) may not produce any effects (since 75 db., 3-6 minutes, and 90 db., 3-6 minutes, do not differ from the control group). Figure 3 suggests some effect of stimulation during the short-term memory period (0-3 minutes) when compared to stimulation during the 3-6 minute period although the relevant contrast in Table 2 (Contrast 13) is not significant ($p < .10$). This seems to suggest that the experiment may not have been sensitive enough to detect these effects. It is quite possible that stimulation during 0-3 minutes or the putative short-term memory period may be equally as effective as stimulation during 6-9 minutes especially since the difference between the combined means of 0-3 minutes is not significantly different from those of 6-9 minutes. The other possibility is that there is certain overlapping of phases in the first 3 minute period in the sense that the short-term memory period may actually be less than 3 minutes and a 3-minute duration of stimulation might have been in excess of what was required.

The important point to be considered in the present data is that a moderate intensity of arousal elicited during the third phase of the memory trace has been effective in improving long-term recall with this effect seeming to disappear at a higher level of stimulation (see Figure 2) i.e., with 90 db. of white noise and, additionally, there being no effect due to stimulation during the first or the second phase.

A plausible explanation of these results could be that during the action decrement phase the trace is relatively unavailable to the organism, resulting in a temporary inhibition of recall. This is presumably due to the fact that reverberatory activity may be at its maximum during this period. This may mean that after a neuron has been increased to its threshold of excitation, it will fire and send a pulse along its axon. However, "once threshold level has been exceeded, the shape and the amplitude of the pulse becomes relatively independent of the intensity of stimulation," (Denes & Pinson, 1967). Hence, further stimulation during the second phase may not induce additional reverberatory activity. This may also be the case with the first phase (0-3 minutes). The learning trial beginning with the first PA sets up the reverberatory activity and by the time the last PA is presented this reverberatory activity may have reached asymptote (perhaps due to cumulative effects of successive PAs) such that any further stimulation has little effect. These results are consistent with Landauer (1969) who states that, "if a reverberatory activity were at a maximum level immediately following a trial, a second occurance of a stimulating event could not produce as much additional reverberatory activity as did the first" (p. 84).

Landauer (1969) also considers that "the optimum timing of an operant reinforcer would in fact depend upon the course of consolidation and the course of decay of post-trial hyperexcitability." He further states "if hyperexcitability lasts for a long time after a trial, then a reinforcer might reinstate activity for a considerable period after the trial, and if overlapping successive excitations are not additive in their consolidation, reinforcement might be much more effective if delayed." (p. 84) He further mentions that human learning is one such situation which has an extended delay gradient as compared with operant reinforcement for bar pressing. His study confirmed this assumption of re-excitation of some of the elements which might have been recently active, thus giving rise to additional consolidation. Thus, it seems that a moderate level of stimulation during the period when the reverberatory activity is slowing down, i.e., between 6-9 minutes, may have helped to re-excite the neurons, which had become sub-threshold, and prolonged the consolidation process. This perhaps is a crucial period, since with a higher level of stimulation the recall scores at this point were lower by almost 15% from the performance of the moderately aroused group. In other words, excessive stimulation at this point may actually disrupt rather than augment reverberatory activity (Landauer, 1969).

Since in this study, noise intensity as such did not have any effects, other arousal-inducing agents may be tried, keeping the same temporal parameters. It may be worthwhile to replicate the present study, perhaps with certain modifications such as breaking down the 9 minute period into four periods of stimulation of 2 minutes duration each. This may help in understanding the overlapping of the phases, i.e., the short-term, the dynamic trace, and the structural trace period. In the present study, the treatment effects may not have shown up due to the difficulty of the PA task used. It may be worthwhile to replicate the study using a PA task of lesser difficulty or perhaps systematically varying levels of difficulty. Additional research may be undertaken to find out what kind of results are obtained if arousal is not manipulated at all and the Ss are tested at the same three points in time used in this study. Such studies may be helpful in understanding and clarifying some of the issues about the temporal parameters of the consolidation process. Then, there is a whole area of research exploring the relationship of consolidation processes to to other processes such as mediation, creativity, etc.

Mediation Latency

As noted in the Results section, intensity of arousal had no effect on mediation time. These results are quite similar to the recall analysis already discussed. An interesting feature of the mediation latency data is its remarkable similarity with the recall pattern for different temporal conditions. Figure 6 suggests an inverted "U" relationship between mediation speed and the temporal intervals and "U" relationship between the recall scores and the temporal intervals. The results are in the expected direction since Ss with higher recall scores also show shorter mediation latencies (Runquist & Farley, 1964). These results are rather difficult to interpret in the context of the present study. The questions that could be raised now are whether the results obtained in the 75 db., 6-9 minutes group are due to real effects of the treatment on the consolidation process or due to the fact that Ss in that condition made greater use of mediators, or is it that inducing moderate levels of arousal during the structural trace period influences mediation speed in some way? The results, although tending to support the last assumption do not throw any light on the processes involved. This inference may not be valid since the arousal was induced on the first day of testing and the mediation data collected after the long-term retention test. Hence, the relationship is not very clear. Further research is necessary on this aspect. Perhaps future studies on consolidation processes using a PA task may incorporate a question at the end to simply ask the Ss whether they used any mediators at all in the learning of the PAs.

Examining the data somewhat differently suggests very little usage of mediators to recall the PAs. This is evident from a non-significant "t" value obtained from a test between mediation latencies for correctly and in correctly recalled PAs. Also the percent of shared variance between mediation time and recall scores was only about 6%. This is perhaps expected since the Ss were not specifically told that they would be asked to recall the PA at a later time and that their attention was diverted from the main purpose of the experiment by instructing them that the main objective was to take a series of physiological measures while they are engaged in different types of tasks. Another possible interpretation could be that all the PAs used in the study were more or less of the same level of difficulty. This is supported by the fact that there were no differences obtained between the mean mediation time for the first three PAs and the last three PAs and that there were only slight differences between the mean mediation latencies reported for these six PAs (see Figure 7). This perhaps also accounts for the low recall scores obtained in the study.

V

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