ELECTROCONVULSIVE SHOCK, RETROGRADE AMNESIA AND THE SINGLE-ECS METHOD

by

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B. S., Reed College, 1961

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

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CHAPTER I

A Review and Examination of ECS and the Consolidation Theory

The "stimulus trace" or a "memory" left by a sensory event is the subject of much current investigation both by psychologists and physiologists. One of the recent techniques of studying this trace is to interfere with it by immediately introducing a second trace. The theory behind this work is traced back to Muller and Pilzecker (1900) who proposed a consolidation or perseveration theory to explain why interference is created. They suggested that in order for a memory trace to become part of the permanent memory, it was necessary for a certain amount of time to elapse for a consolidation process to take place, during which it was not necessary for the stimulus to be present. Meanwhile, the memory trace is subject to disturbance while in its unstable state. If any disturbance does occur, the process of consolidation would be interferred with and interference would be produced for memories immediately preceeding the disturbance, with a resulting memory impairment.

Soon after the Muller and Pilzecker paper, Burham (1903) related the consolidation theory to the phenomenon of retrograde amnesia (RA) by proposing that lapses of memory immediately before a traumatic disturbance (shock or unconsciousness from a severe blow to the head) could be explained by the disruption of the stimulus perseveration process. The phenomenon of retrograde amnesia was suggested to be the result not only of disruption of "a process of making permanent im-

pression upon the nerve cells, but also a process of association, of organization of the new impressions with the old ones". (Burham, 1903)

What was needed was an experimental approach to the consolidation theory that provided a simpler situation than that of verbal learning which investigates two traces in an interference situation. Thus an experimental approach using one trace and a disruption process would provide a situation where just the consolidation of one trace could be studied without possible conflicting effects of a second trace.

The Case for an RA Interpretation of the Effects of ECS.

Zubin and Burrera (1941) were among the first to study the consolidation process experimentally using electroconvulsive shock (ECS) as a disruption technique. Their general experimental paradigm, usually followed by more recent studies, is a training-ECS-test sequence, i.e. a short training period followed by ECS, after which retention is tested for. Zubin and Burrera (1941), using one sequence a day, found that patients given a verbal learning task (a paired-associates list) and then given ECS (or no ECS where the same subjects were used as their own controls), resulted in differences on savings scores with the ECS group having the lowest scores indicating a memory loss or RA. The authors suggested that the time between training and ECS might be critical since those subjects trained the previous night performed better than the subjects trained in the morning. Both groups received ECS in the afternoon and were then tested at night.

This time relationship was studied by Duncan (1949), who used rats as subjects in an escape-shuttle box training situation. He gave 18 sequences over 18 days, one sequence a day. The time relationship was

studied by using training-ECS intervals ranging from 20 sec. to 14 hours. The greatest decrement in test scores was found on the smallest training-ECS interval and then fell off sharply for longer intervals. Two important advances had been made with these two studies: a technique that would produce experimental RA was found and the existence of a perseveration or consolidation process was suggested.

The Case Against the Existence of RA.

The major reaction against the RA interpretations of the results of the Zubin and Burrera (1941) and the Duncan (1949) studies came with the publications of Coons and Miller (1960) and Adams and Lewis (1962a, 1962b, 1963). Briefly the argument of Adams and Lewis was this:

> "... convulsive shock serves as an unconditioned stimulus which elicits a prepotent unconditioned response, the convulsion. This convulsion, or part of it, becomes conditioned to stimuli (or their traces) present at the time of convulsion, and competes with (replaces) any other learned responses to the conditioning stimulus. Thus the retrograde amnesic effect is due to the replacement of one response with another." (Lewis and Adams, 1963).

A demonstration of this approach (Adams and Lewis, 1962a) involved giving albino rats training in a Miller-Mowrer two compartment shuttle box where one side was electrified 10 seconds after a flickering light came on. If the rat escaped before the shock occurred a success score was given. Four groups were used: Group I (T-NECS, training-no ECS) received one avoidence trial per day for six days; Group II was treated the same as Group I except an ECS was given after every trial (T-ECS); Groups III and IV received no training, with Group III receiving ECS (NT-ECS) and Group IV receiving

no ECS (NT-NECS). On retention, Group I (T-NECS) received the highest savings score with Group IV (NT-ECS) receiving the next highest and Groups II (T-ECS) and III (NT-ECS) having about the same scores.

Their results demonstrated that the rats who were not trained but given ECS (NT-ECS) would not perform any differently than those who had received training and ECS (T-ECS), suggesting that ECS does not produce amnesia, but does produce a deficit in performance because of fear. Lewis and Adams (1963) state that:

> "When the Ss are placed in the shock box after a few ECS treatments there, they immediately, and very obviously, crouch and tremble. The conditioned crouching interfers very strongly with the previously learned jumping response (to escape) and also with the to-be-learned jumping response."

Adams and Lewis (1962b) also found, under the same conditions as above, administering ECS in a different situation than the goal box results in retention almost equal to that of the controls who had no shock. However this retention is considerably above that of the rats given ECS in the training situation. It was suggested on the basis of this evidence that the consequences of the ECS were stimulus bound. In addition to this result, Adams and Lewis also showed that extinguishing the animal by leaving him in the training situation where the ECS was given would produce better relearning than the same treatment with no extinction.

The position of Coons and Miller (1960) is similar to that of Lewis and Adams (1963). Coons and Miller hypothesized that RA may "be an artifact of repressive processes produced by unpleasant associations formed between trauma and thoughts about events immediately preceeding it." They were led by this hypothesis to replicate Duncan's original experiment (1949) where four groups of albino rats

were given shuttle box training of one trial per day. ECS was given at 20 seconds, 60 seconds and 1 hour after the trial to three groups while the fourth group had subconvulsive electric shock (pseudo-ECS). It was found that on retention trials, the sooner a group's ECS came after the trial, the worse its performance during learning. The emotionality of the animals during this time was measured in terms of defecation and urination scores. These measures showed that the grid shock and ECS groups had the highest emotionality scores, therefore confirming Coons and Miller's position on the emotionality producing effects of ECS. The indications of emotionality found on this study prompted Coons and Miller to do further work.

As the second part of their study, Coons and Miller (1960) gave the animals one trial a day for 12 days in a shuttle box where they were trained to escape from the black side to the white side. After training, the animals were tested by electrifying the white side instead of the black side and ECS was then given after every avoidance response to the white side where they were shocked. ECS was given at 20 seconds, 60 seconds and 1 hour after every trial. According to the consolidation theory, the sooner ECS occurs after the trial, the greater the disruption of the memory engram. However Coons and Miller discovered just the opposite. Relearning was best with 20 seconds, next best with 60 seconds and worst with the 1 hour group.

There are differences in viewpoint between Coons and Miller (1960) and Lewis and Adams (1963) that should be examined. According to Lewis and Adams' (1963) competing response theory, the trained

response is interferred with, e.g. running away from the black side. Lewis and Adams then characterize Coons and Miller's aversion explanation as predicting that the fear produced would cause crouching, a physical response not compatible with running away. Therefore differential predictions would be generated since one would predict that Lewis and Adams' animals would forget (or would not escape) because the stimuli preceeding the shock would also give rise, through conditioning, to the residual effects of the ECS and these compete with the escape response. On the other hand, the Miller and Coons rat would react with fear depending on the situation in which ECS was given; if ECS was given in the shock side of the box, they should run away from it, and give evidence of faster learning than the controls. As a quick characterization, it might be said that the Miller and Coons rat is afraid of the ECS situation and the Lewis and Adams rat is confused by it.

Although Coons and Miller's (1955, 1960) and Adams and Lewis' (1962a) findings demonstrated that earlier studies failed to contend with the factor of aversion, they do not deny the existence of a consolidation process. In fact their findings were already clearly anticipated by Friedman (1953) who first showed that aversion was a factor that tended to confound RA.

Friedman (1953) gave six groups of rats training in a Skinner box after which the experimental groups were given shock for any approach tendencies toward the bar. Group I was given ECS in the training situation, Group II were controls who had ear clips but no ECS and no shock, Group III were controls with no shock, Group IV was given ether

anesthesia and then ECS, Group V was given ECS in another environment and Group VI was given grid shock. The inhibition of the bar pressing by ECS was greatest for Group VI and then in decending order - I, V, IV, III and II. It was also shown by emotionality indicators (defecation and urination measures) that Groups I and VI were more emotional that any of the other groups. From this data Friedman concluded that there are signs of aversion when taking into account the defecation and urination measures. He also concluded that there were differences between ECS given in the training situation and ECS given in a different situation, suggesting a situational aversive conditioning effect due to ECS. The comparisons between Groups I and VI show that ECS does not set up as much aversion as grid shock, suggesting that the ECS group evidenced RA effects since otherwise the two groups should have been similar. Friedman came to the conclusion that both aversion and RA effects are produced.

Since Coons and Miller (1960), Duncan (1949), Lewis and Adams (1963) and Friedman (1953) all used repeated-ECS sequences, their investigations of RA are biased to the degree that their test procedures were sensitive to ECS-produced aversive effects that would confound RA effects. This state of affairs has demanded a procedure that would somehow eliminate or control these aversion effects in order to produce clear RA effects. The one-ECS technique described below was employed in an attempt to solve this problem.

The Single ECS Technique: The Solution to a Problem.

A technical conclusion to the argument of the existence of RA and thus existence of the consolidation process is to be found in the work

of McGaugh and his associates (Madsen and McGaugh, 1961; Hudspeth, McGaugh and Thompson, 1963; and McGaugh and Madsen, 1964) and Jarvik (1961), Weissman (1963, 1964) and Heriot and Coleman (1962). Briefly, their position is that giving one sequence of train-ECS-test will not involve the degree of aversion that a procedure using repeated sequences will involve.

An example of this new technique can be found in the McGaugh experiments cited above. Using a jumping platform developed by Jarvik (Pearlman, Sharpless and Jarvik, 1961), McGaugh (1961) shocked the rats on the floor after they had jumped off a platform and then during the next 5 seconds the experimental group (N-47) were given ECS, while the controls were not (N-49). The ECS (0.2 sec., 25 ma.) produced grand mal seizures in all except 8 experimental animals. Only one avoidance trial and one ECS were given. The experiment was constructed so that effects of ECS aversion would be in opposition to the effects of RA; if the rat's memory were not disrupted by the ECS and it only "remembered" the shock on the floor and the "aversion" to the ECS when he jumped off the platform, it would not jump quickly; on the other hand if the rat's memory were disrupted, it would not remember the shock on the floor and would jump quicker. McGaugh found 26 out of 49 control animals avoided jumping while 8 out of 47 experimental animals avoided jumping, showing proof of RA.

Recently there have been reports of studies dealing directly with the difference between the one-ECS and the repeated-ECS technique. Hudspeth and his associates have shown that aversive effects produced by ordinary shock become much more intense over trials than the aversive effects produced by ECS (Hudspeth, McGaugh and Thompson, 1964)

and that aversive effects produced by repeated sequences using ECS are much stronger than that produced by the first sequence, (Hudspeth et. al., 1964). Also, the rat's aversion to ordinary shock on the floor after jumping from a platform is greater than that of rats that jump, receive a shock, then ECS in the single-ECS situation (Madsen and McGaugh, 1961). In addition, Hudspeth et. al. (1964) have shown that when the rat steps from the platform to the floor, and is given ECS alone with no shock, aversion will be built up across trials whether the ECS is given immediately, 30 minutes or 1 hour after the rat jumps. But this aversion is not as great as that built up using both ECS and shock. Nevertheless, these results do not show that the confounding still does not result from aversion; it only shows that there is less aversion when the single-ECS method is used, rather than sequences of ECS, or just plain shock. Additionally, the training-ECS interval, according to Coons and Miller, should not make any difference to the amount of aversion effects produced since the ECS is still given in the training situation. Nevertheless, Hudspeth, et. al. (1964) have found the interval length does produce differences; again supporting the consolidation explanation, since memory consolidation increases as the interval between training and ECS increases, giving rise to different amounts of RA.

Although performance measures have suggested some differences in aversion in one-ECS and in repeated-ECS situations, other measures have been used to provide additional data.

Aversion and it's Measures.

Two different types of measures have been used to support the notion that aversion effects result from ECS in repeated sequence experiments. For instance, Coons and Miller (1960) using learning measures conducted their study so that aversive effects should oppose rather than summate with any effects of retrograde amnesia. Emotionality measures were also obtained to provide behavioral evidence of the aversion effects. Both Friedman((1948) and Coons and Miller (1960) found empirical support for their theories concerning the aversive effects of ECS by emotionality measures.

Some remarks should be made about the suitability of emotionality measures. Hall (1934) was among the first to suggest that defecation and urination were valid measures of individual differences in emotionality. This point is supported by the evidence of Hunt and Otis (1953) who found that defecation in rats, during the presentation of a fear-arousing conditioned stimulus, increases progressively during conditioning and declines during extinction. However Fuller and Thompson (1960, p. 150) make the point that:

> "Changes in autonomic function do, of course, accompany behavioral arousal, but the nature and intensity of such reactions probably are as much a function of inherited effector sensitivity as of differential emotionality."

In a similar vein, Bindra and Thompson (1953) found non-significant correlations between emotional elimination and performance in tests of timidity and fearfulness and from this stated that "defining a trait of emotionality by an autonomic response is justified only as an approximation." It might be summarized then, that the use of emotionality measures such as defecation are valid only in the group

case because of individual variability of autonomic responses and even then, these measures are only approximate. Only with these reservations in mind, can the use of emotionality be justified.

Friedman (1948) took both defecation and urination scores in his study (using ECS) and found both measures yielded large scores for the "grid shock" and the "ECS in the training situation" groups. However low scores were found with "ear clip", "normal control", "ether, then ECS", "ear clips but no ECS", and "ECS in other environment groups". This data can be interpreted as indicating that those animals receiving either grid shock or ECS in the training situation over an extended number of trials become quite emotional. This emotionality was also directly correlated with low performance on bar pressing (the performance measure). Coons and Miller (1960) obtained very similar results, so it might be concluded that emotionality scores are consistant with arguments as to the aversive effects of repeated trials of ECS.

The Electroconvulsive Seizure and RA.

The rationale for using electroconvulsive shock instead of just an ordinary electric shock to disrupt memory has resulted from the very obvious memory deficits found in the recollections of those patients undergoing ECS treatment. The original case studies cited by Burham (1904) pointed to memory deficits resulting from head injury. The necessity of using a very intense stimulus or injury to the organism to produce a noticable amount of RA seems to point out an interesting difference between memory disruption procedures and ordinary competing response procedures. It has been suggested by

several investigators (Stainbrook, 1946; Finger, 1947; Glickman, 1961; and Deutsch, 1962) that the function of the disrupting stimulus is not that of a competing response as Lewis and Adams (1963) maintain but rather of an actual physiological event such as anoxia produced by ECS (Stainbrook, 1946) or hemorrhage (Bjerner, Broman and Swensson, 1944). This is not to say that the ECS may also have competing response components; however, it does seem to have a gross physiological effect.

Of importance here is the work on ECS and ether combined. It has been found by several investigators that ECS, given while the animal is under deep ether anesthesia, will result in only a jerk in the body with no convulsion and little, if any, RA (Porter and Stone, 1947; Hunt, Jernberg and Lawlor, 1953). It is known that ether, pentobarbital or pentylenetetrazol of ether will produce RA although not to the degree as that produced by the seizure agents (Pearlman, Sharpless and Jarvik, 1959, 1960). Thus without the seizure, little RA is produced and this amount of RA is probably due to the RA effects of ether. Therefore although some RA will still result, ether can successfully block a seizure. The effects of ether on the ECS and the seizure seem to suggest that the seizure is only sufficient for RA to occur but will produce more RA than will anesthetics.

The occurrence of a seizure thus appears important in disrupting memory; however, it has also been shown by Weissman (1964) that after the seizure has taken place, sometimes RA would not be produced in an individual rat. Further, it is interesting to note that in almost every ECS study using rats as S's some of the rats had to be excluded because the ECS administered to them did not produce a grand-mal seizure.

Weissman (1963; 1964) has explored the seizure no-seizure dimension using the one-ECS technique and has found that a seizure soon after training is necessary to produce suitable amounts of RA. The results of ECS given an hour after training versus that given 5 minutes and ½ hour after training (Weissman, 1964) would suggest a physiological change or damage of very specific proportions. For instance, the immediate ECS produces a great amount of RA while that given an hour after produces little, if any, RA. This seems to suggest that the role of ECS is that of disruption; if ECS provided only a competing response as Lewis and Adams (1963) suggest, a very traumatic ordinary shock would produce RA.

The importance of an ECS-induced seizure is complicated by the fact that seizures can be produced by insulin (Glickman, 1961), and audiogenic (Stern and Gollender, 1963) techniques as well by ECS. However since RA can be produced by other methods such as ether (Porter and Stone, 1947), spreading depression (Bures and Buresova, 1963; Pearlman and Jarvik, 1961) and anoxia (Hayes, 1953), it is evident that the seizure is not always necessary for RA. The existence of RA has been confirmed by these other methods so that the present study can be viewed as an attempt to clarify some technical problems, rather than a defense of RA when using ECS.

In conclusion, it should be mentioned that at no time has a report been published that has found complete RA after an ECS or a series of ECS's. Especially with the Madsen and McGaugh (1961) and Pearlman, Sharpless and Jarvik (1961) studies which used only a 4 sec. interval between training and ECS, 100% RA should occur if the grand-

mal seizures were effective. However, even this short interval may not be effective because some consolidation processes may be extremely rapid, or because the seizure simply may not produce total RA. At present, there is no way to differentiate between these two conditions.

The Physiological Implications of ECS and the Occurrence of RA.

Some authors have attempted to explain the results of ECS on retention as a case of physiological effects on performance (Riess, 1948; Russell, 1948). Riess (1948) cites the implications of Selye's work (1956) on stress to suggest that a series of ECS's will produce "adaptation syndrome" effects. Essentially, Selye's theory states that under widely differing stress-producing situations, there are three reaction stages which develop as the stimulation continues: (1) shock; (2) changes in certain factors resulting in adaptation and improved physical condition of the organism with more than normal resistance to the stress built up; (3) the organism reverses the changes in certain factors and the resulting deterioration usually ends in death. More specifically:

> "Stress is defined as the state which manifests itself by the G.A.S. (general adaptation syndrome). The latter comprises; adrenal stimulation, shrinkage of lymphatic organs, gastrointestinal ulcers, loss of body-weight, alternations in the chemical composition of the body, and so forth." (Selye, 1956, p. 47)

Selye found that these symptoms were produced when, for instance, a disease struck a local area. The G.A.S. is a generalized response to this stress and includes actions of the nervous system and then of the endocrine glands, especially the pituitary and the adrenals. These

glands produce two classes of adaptative hormones; anti-inflammatory hormones such as ACTH (adrenocorticotropic hormone), cortisone and cortisol (COL) which inhibit excessive bodily defensive reactions; and the proinflammatory hormones; among which are the somatotrophic hormone (STH), aldosterone and DOC (desoxycorticosterone).

General adaptation syndrome (G.A.S.) effects have been reported as related to ECS although the studies have not been done in the context of Selye's theory. For example, many investigators have found that as the number of ECS trials (usually one per day) increased, various effects were found such as weight loss (Coons and Miller, 1960; Russell, 1948), hemorrhages (Russell, 1948), increases in adrenal corticoid excretion (Cleghorn, Goodman, Braham, Jones and Rubles, 1948), changes in circulating leukocytes and increases in uric acid excretion (Parsons, Gildea, Ronzoni, and Halbert, 1947), increases in adrenal weight and depletion of adrenal ascorbic acid content (Royce and Rosvold, 1953). All of these effects have been listed as products or bypproducts of stress (Selye, 1956). However there has been no work yet reported concerning any of these adaptation syndrome effects on a single-ECS situation. In addition, it is interesting to note that these phenomena of stress only become noticable over the course of repeated ECS and may not occur in the single ECS situation.

As a step toward investigating the physiological effects of ECS, the relationship suggested between repeated ECS and stress was tested by Moyer and Moshein (1963) who evaluated ECS effects on three groups of rats; one group was sham operated; one group had bilateral adrenalectomies and the third group was the unoperated control. The results revealed that ECS significantly attenuated the conditioned

avoidance response in all groups with no differences found between groups. It was concluded that the adrenals are not necessary for ECS to attenuate an avoidance response. However stress effects may be produced by other glands and ECS might still attenuate an avoidance response by its stress effects.

Evidence which would support Selye's position was presented in his book (Selye, 1956), where studies were cited to suggest that DOC diminishes the intensity of an ECS seizure while the COL would increase it (Selye, 1956, p. 173). Also DOC can, under certain conditions, produce brain lesions such as are often seen in old people. There are also effects of DOC on the renal and cardio-vascular systems and these effects are usually forms of damage such as enlargement of the heart muscle, thickening and hardening of the arteries and blockage of the renal tubules in the kidneys with albuminous precipitate. It was also suggested that STH, a pituitary secretion, produces this damage, but STH might instead have produced the secretion of DOC by the adrenals (Selye, 1956, p. 136).

Effects of ACTH and COL on mental states have proved interesting. Both hormones may first cause a sense of well being with excitement and insomnia and then this is sometimes followed by deep depression. Selye (1956, p. 174) mentions that investigators have found "heightened perception" and the "dissociation of the ego and the id" as resulting from ACTH and COL. These results seem somewhat similar to those reported by Gallinek (1956) who reported that after ECS therapy, patients would often manifest "a temporary annihilation of the sense of familiarity" and he hypothesized that this "provokes basic anxiety,

and results in a strong, progressively increasing fear of the treatment." This, in fact, was part of the evidence cited by Coons and Miller (1960) as suggesting some kind of aversive effects which led them to their study suggesting the confounding of the effects of RA with aversive effects.

Other evidence of possible physiological effects or damage have appeared in the literature on EEG (electroencephlagraph) work in humans. After a series of six ECS's, Procter and Goodwin (1942) found a change in the EEG in the direction of abnormality with an increase in delta rhythms. Further "the appearance of marked slow wave activity was paralleled by such clinical abnormalities as acute confusion and other unfavorable symptoms", (Procter and Goodwin, 1942). Recently, work by Green (1960) has compared the threshold and duration of seizures against the degree of delta change measured during the course of treatment. There was a positive relationship found between the duration of the seizure and the amount of delta rhythm produced. However Green (1960) found no relationship between the threshold for the initial treatment and the amount of delta activity induced during treatment. A critical factor here could be an increase in seizure duration across therapy with no necessary relationship to the seizure threshold. It is, for instance, will known that the threshold increases across treatments even when one ECS is given a day, and the duration of the seizure would be affected.

Loss of weight is one of the most nonspecific consequences of chronic stress. According to Selye;

> "It is due partly to loss of appetite, but partly also to the fact that a surplus of anti-inflammatory hormones tends to facilate a kind of "self-combustion." In times of great stress, much caloric energy is needed and since food-intake is usually diminished, it is very important for the preservation of health that the body should burn its own tissues to supply calories for resistance. But, of course, if this goes on for a long time, pathologic emaciation will result." (Selye, 1956, p. 182)

Russell (1948), Coons and Miller (1960) and others have noted the fact that there were differences in weight loss between control, plain shock and ECS animals such that the ECS group lost most if not all of the total weight lost. It has been accepted that this weight loss is generally found and it agrees with Selye's predictions.

To sum up, there have been various indications of physiological effects of the ECS which range from EEG abnormalities, weight loss, hemorrhages, increases in adrenal weight to increases in adrenal cortical excretion. These various phenomena, found by investigators, independent of Selye's theory, all seem to point up the very possible conclusion that the ECS is a stress agent and produces general adaptation syndrome effects. There are, in turn, indications that these effects, especially those of the hormones DOC and COL,will effect the duration of the seizure. Evidence furnished by Green (1960) suggests that the duration of the seizure is correlated with behavioral malfunction. Thus there seems to be evidence for general adaptation syndrome effects in the repeated-sequence ECS situation.

Although theoretically, the case of continued stress is not met in the single-ECS method, care should be taken to guard against any possible influence. The importance of this factor has not been evaluated yet, but there are cases (Madsen and McGaugh, 1961; Weissman, 1963; and Heriot and Coleman, 1961) where the ECS in a single ECS technique was given in other than the training situation, and

although aversive effects to the training situation was controlled for, the adaptation-syndrome effect was not. The appropriate control for this effect is the comparison of ECS-training groups with training-only groups, testing for differences in learning.

Conclusion and Statement of the Problem.

The main difficulty with the above research is that it has only shown that RA can be distinguished from aversive effects. However, this distinction between RA and aversion is not enough; the possibility that confounding still results does not destroy the distinction but does leave doubt as to the amount of confounding still present. If it can be found that there are no significant aversive effects, whether of the Coons and Miller (1960) or of the Lewis and Adams (1963) type, then the one-ECS technique is a suitable instrument for further stuey of the parameters of the consolidation process.

Emotionality indicators also suggest the existence of aversion effects in the repeated-sequence ECS situation. If these emotionality indicators are not found in the one-ECS situation, then it might be concluded that aversive effects of ECS do not exist in that situation.

There is also the question of the physiological effects of ECS on performance. The behavioral effects due to aversion might instead be due to the stress effects of ECS. If this is true, then the general adaptation syndrome (Selye, 1956) would seem to be the physiological reaction responsible for the confounding "aversive" effects. If these physiological effects were found in the one-ECS situation, they could be predicted to have effects no matter when the ECS was given.

Because of the above considerations, it was decided to test for RA, aversion and adaptation-syndrome effects to see what element of variance each contributes to a specific experimental condition.

CHAPTER II

Method

Subjects.

Albino rats of the Sprague-Dawley strain were divided into five groups of 6 rats each, giving a total of 30 male rats. All Ss were between the ages of 85 and 95 days at the start of the experiment, and were on ad lib feeding and watering schedules.

Apparatus.

A clear plastic Miller-Mowrer avoidance box was divided into two areas by covering one side with black cardboard and the other with white cardboard. The floor consisted of two sections of electric grid coinciding with the two areas. Only the black side was capable of being electrified.

The ECS apparatus consisted of a high voltage neon transformer (4500 VAC) with a Hunter-style electric timer giving a 60 ma. current across a 30,000 ohm resistor for 0.3 sec.[1] The ECS apparatus was pretested and found capable of producing a full tonic-clonic seizure with little risk of damage to the animal. The damage usually found is that of fractured vertebrate resulting from the initial seizure.

The aversive shock given to the rats through the grid of the avoidance box was of the order of 100 VAC from a Campbell-type rat shocker with constant current settings. ECS was administered to the

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1. The advantage of using a neon type transformer is that there is a special magnetic shunt built in that limits the current no matter what the resistance. In this case a 60 ma. neon tube transformer was used.

ears using alligator clips covered with cotton moistened with a sodium bicarbonate solution.

Procedure.

All groups were given five training trials in the Miller-Mowrer avoidance box. Before the grid shock, a 10 sec. buzzer sounded and stopped as the shock was delivered. Rats were originally placed on the black (shock side) and were freely allowed to cross to the white side after the buzzer started to sound. However, they were restrained by E's gloved hand from crossing before the buzzer onset. After their escape, they were gently moved by E's gloved hand to the black side again. All rats were freely allowed to escape as soon as the buzzer sounded except on the first trial in which they were required to experience the shock.

Animals in Group I (see Table 1) were given ECS in the black side of the avoidance box on a table in the room 24 hours before training while those in Group II were given ECS on the gray stone floor of the experimental room. The black side of the box had both shock and ECS given in it so that any situational aversive effects of the ECS would decrease rather than enhance any RA. Animals remained in their ECS surroundings for 1 minute before the ECS was given. Group III was the control group with no ECS given.

Animals in Groups IV and V were given ECS immediately after training, which took at most 4 minutes to complete. Rats in Group IV were given ECS in the training box as were those in Group I, while rats in Group V were given ECS on the floor the same as those in Group II.

Table 1. The Training and Testing Procedures for all Groups.

Group I	ECS in training situation	- 24 hr -	5 training trials	- 24 hr - 10 test trials
Group II	ECS in other situation	- 24 hr -	5 training trials	- 24 hr - 10 test trials
Group III			5 training trials	- 24 hr - 10 test trials
Group IV			5 training trials plus ECS given directly after in training situation.	- 24 hr - 10 test trials
Group V			5 training trials plus ECS given in other situation.	- 24 hr - 10 test trials

Twenty-four hours after training, 10 retention trials were given. These consisted of retraining trials under the same conditions as the original five trials, except there was no forced shock on the first trial.

The response measure was that of failure to run when the buzzer came on, with the result that the animal received shock. The scores were then transformed by the square root transformation $\sqrt{X+1}$ to meet the assumptions of the analysis of variance test which would have been violated since the distribution of the raw data was in the general form of a Poisson distribution.

Emotionality was measured in terms of defecation scores. The number of feces during the training and retention trials were counted for each rat. A transformation was not used on these scores.

CHAPTER III

Results

The raw data obtained from "failure to avoid shock" (error scores) are summarized in Table 2. These data suggests some distinct differences between the groups which appeared to point out the difference between the one and repeated-sequence ECS studies.

The raw data were first transformed and then subjected to an analysis of variance. The analysis of the error scores on the training trials revealed no differences between groups (see Table 3); this result would be expected if RA alone was produced. However, when the test trials were analysed, differences were found that suggested some sort of RA effect in Groups IV and V vs. III (see Table 4).

The scores on the ten test trials were then broken down for analysis using orthogonal comparisons (see Table 5). The comparison I vs. II was nonsignificant as were IV vs. V, and I and II vs. III. The lack of significant differences between groups would suggest that situational aversive effects of ECS did not occur. Also, these comparisons would suggest such situational effects would not appear whether ECS was given before (I vs. II) or after training (IV vs. V). The comparison of the two "performance" groups with the control group, I and II vs. III, suggested, finally, that there were no differences between these groups as a function of ECS prior to training.

Table 2. Total Number of Failures to Avoid Shock for Each Group.

Trials	Groups I	II	III	IV	V
5 training	21	17	21	23	25
1-5 testing	10	12	7	16	16
6-10 testing	5	5	6	12	6
Total test trials	15	17	13	28	21

Table 3. Analysis of Variance for 5 Training Trials Using Transformed Error Scores.

Treatments	df	SS	MS	F
Groups	4	.33	.0825	1.42 ns
Within	25	1.45	.058	
Total	29	1.78		

Table 4. Analysis of Variance for 1-10 Test Trials Using Transformed Error Scores.

Treatments	df	SS	MS	F
Groups	4	1.41	.352	2.83*
Within	25	3.11	.124	
Total	29	4.52		

* $p < .05$

Table 5. Orthogonal Comparisons Between Groups on Retention Test Trials 1-10 Using Transformed Error Scores.

Comparisons	$D^2 / n\Sigma a$	F
I vs. II	.04	.32
IV vs. V	.12	.97
I and II vs. III	.086	.69
IV and V vs. III	1.00	8.04*
I, II and III vs. IV and V	1.16	9.32**

* $p < .01$

** $p < .005$

The comparisons of Groups IV and V vs. III and of I and II and III vs. IV and V were significant at the .01 and .005 levels respectively. It is suggested that in view of the first comparison there are significant effects of the ECS given after training when compared to the control group with no ECS given after training. In addition, when the control and prior ECS groups were pooled together in the second comparison, the effects of ECS given after training are still apparent.

Using defecation as a measure of emotionality (see Table 6) no differences were found on the training trials (see Table 7). This again suggests no detectable effects of ECS given prior to training. However, analysis of the test trials suggests differences at the 97.5% level of confidence (see Table 8). Since this was similar to the findings using error scores, orthogonal comparisons were carried out using the same comparisons as used on the error scores.

The linear comparisons of both I vs. II and IV vs. V (see Table 9) gave nonsignificant F ratios. These comparisons were consistent with those comparisons using error scores (Table 7) because there were no situational ECS effects. The next three comparisons (I and II vs. III; IV and V vs. III; and I, II and II vs. IV and V) were all significant at the .05, .005, and .025 levels of significance respectively. What seems to differentiate these comparisons from those using error scores, is that the control group had the highest emotionality scores and the performance groups (I and II) had the next highest, with the RA groups (IV and V) having the lowest scores. However the difference between the RA and performance group was not

Table 6. Total Defecation Scores for Each Group.

Trials	Groups I	II	III	IV	V
Training 1-5	21	17	21	23	22
Testing 1-10	28	25	40	25	12

Table 7. Analysis of Variance for 5 Training Trials Using Defecation Scores.

Treatments	df	SS	MS	F
Groups	4	6.0	1.5	.359 ns
Within	25	104.2	4.17	
Total	29	110.2		

Table 8. Analysis of Variance for 10 Test Trials Using Defecation Scores

Treatments	df	SS	MS	F
Groups	4	61.5	15.37	3.79**
Within	25	101.7	4.06	
Total	29	163.2		

** $p < .025$

Table 9. Orthogonal Comparisons between Groups on Retention Trials 1-10 Using Defecation Scores.

Comparisons	$D^2 / n\Sigma a$	F
I Vs. II	.75	.18
IV vs. V	12.0	2.96
I and II vs. III	18.78	4.63*
IV and V vs. III	49.00	12.07***
I, II and III vs. IV and V	29.77	7.33**
I and II vs. IV and V	10.67	2.63

* $p < .05$

** $p < .025$

*** $p < .005$

significant when tested (I and II vs. IV and V). Thus the ECS seems to have equal effects on all groups which could be characterized as inhibitory when compared to the control groups which had high emotionality scores.

The use of the present one-ECS situation has apparently done away with situational effects. Thus, the conditioning of situational ECS aversive effects is not a factor in this experiment.

Effects of ECS before or after Training.

The failure of prior ECS to influence performance is important in two ways; first there were no prior-ECS performance effects present where they would have been predicted by the theories of Lewis and Adams, (1963), (the comparison between Groups I and II vs. III), second, the absence of performance effects is enhanced by the fact that RA was observed in the group receiving ECS after training (the comparison between Groups IV and V vs. III). Thus, if the experimental design were capable of showing RA effects for ECS after training, prior ECS effects should have also been found. Therefore since Poschel (1957) and Lewis and Adams (1963) reported prior ECS effects in the repeated-ECS situation, the difference between repeated-ECS and one-ECS situation could be explained by the absence of aversive effects in the one-ECS situation.

Since the "performance" groups' (I and II) ECS is given 24 hours prior to training, and the differences expected on training did not result, it might be inferred that there were no effects on performance as a function of prior ECS in comparison to controls (Group III). If the evidence of RA found in the comparisons IV and V vs. III were caused by ECS effects on performance, there should have been the same effects found in the comparison of groups I and II vs. III since aversive ECS effects should have been the same in both cases. The performance groups' results (I and II) have not revealed the confounding ECS aversive effects that were predicted.

The ECS has been said to have other effects than that of disruption, i.e. stress effects, competing response effects, and fear effects. The stress effects might be broadly classified in a functional context in the following manner: (1) physiological effects that prevent an animal from using its usual peripherial sensory and motor apparatus, (2) physiological effects on the mental apparatus that are necessary to retrieve a memory and (3) physiological effects on the ability to learn in the test situation. If the stress effects are present, then it would be predicted that the performance groups (I and II) would differ from the control group on either the test or training trials. On the other hand, both the competing response and fear theories would suggest differences both between situations where ECS was given (I vs. II, and IV vs. V), and between performance and control groups. However, no such differences were found either on the training or on the test trials for these groups. Since there were no differences found the conclusion must be drawn that either these ECS side effects do not exist in the one ECS situation, or that the training situation is not sensitive enough to find them. The latter conclusion is rendered suspect by the finding of RA in the training situation and thus the former conclusion would seem to be more justified.

Effects of ECS on Emotionality Measures.

Although no significant differences in emotionality were found in training using defecation scores as a measure, there were differences in the test situation. When broken out by linear comparisons, it appears that there were no situational effects due to

ECS given inside or outside the training situation. This confirms the lack of significant differences between I vs. II and IV vs. V using error scores in the learning situation. However, there were significant differences between control (III) and "performance" groups (I and II), between control (III) and RA groups (IV and V), and between control and performance versus RA groups (I, II and III vs. IV and V).

The differences uncovered using orthogonal comparisons suggests that there are effects of ECS in the "performance" and RA groups such that less emotionality was shown in these groups than in the control group. Since there were no significant differences found between the "performance" and RA groups (I and II vs. IV and V) it might be inferred that there were negligible differential effects of ECS in comparison to no-ECS. These findings directly contradict the explanations of the findings in the literature on ECS repeated sequences such as in the studies of Friedman (1948), Coons and Miller (1960), etc. These researchers all found that grid shock and ECS groups were both high in defecation with no differences between them. Not only has the present study found ECS groups not to be high, but ECS groups were in fact lower than the control group.

The findings on emotionality suggest that the ECS actually does have the effect of reducing emotionality, yet these effects are on emotionality and are not on performance as has been shown. In view of the results, it can be concluded, that there are ECS side effects on emotionality that can be distinguished from its postulated disruptive effects on performance and learning.

Conclusions Drawn from the Effects of ECS.

The effects of ECS in the repeated ECS situation have already been dwelt upon. It is apparent that the conclusions drawn from repeated-ECS experiments and the criticisms associated with them are not relevant to the one-ECS experiment. The results of the repeated ECS experiments may or may not be confounded with aversive effects. However, it has been shown that the one-ECS situation is apparently not sensitive to aversive effects. Thus RA produced by a one-ECS technique is capable of offering a sharper tool for study of the consolidation process. The aversive effects that would have been predicted by Lewis and Adams (1963) and Coons and Miller (1960) did not appear. Therefore the criticisms of consolidation theory by these authors applies only to earlier, repeated-ECS experiments. In addition the present experimental results do not reveal any behavioral effects that might be associated with physiological stress of the kind that would be predicted from the general adaptation theory of Hans Selye (1956). A possible exception to this statement might be found when emotionality is measured by defecation rates. However, the results were contradictory to those found in repeated-ECS experiments and might suggest some different physiological effects, (e.g. inhibiting effects).

CHAPTER V

Summary and Conclusion

It was argued that the ECS method of producing RA was a suitable technique if used in a one-ECS training session. Various explanations for the aversive and physiological effects appearing in repeated-ECS experiments suggested the necessity for testing for these effects in the one-ECS situation. Five groups of six animals each were tested under five conditions of avoidance training and ECS: Group I was given prior ECS in the training situation and then trained 24 hours later; Group II was given prior ECS in another situation and was trained 24 hours later; Group III was given training and was the control group; Group IV was given training and directly after was given ECS in the training situation; and Group V was given training and directly after was given ECS in another situation. Twenty-four hours after training the animals were given ten retraining trials. During both training and retraining, defecation scores were taken to obtain an emotionality measure.

The data obtained from "failures to avoid shock" were analysed and revealed no differences between groups on training trials. However differences between groups IV and V vs. I, II and III were found, suggesting RA effects. Since differences were not found on training, it was concluded either that there were no effects of the prior ECS or that the experimental design used was not sensitive to the differences. The former reason was judged more likely since the RA results found in this design would suggest the training situation is sensitive to ECS effects.

The results of the emotionality measure were not similar to those results using error measures in learning as only the control group had high emotionality scores in comparison to the other groups (who were given ECS). These results do support the idea of the one-ECS technique being quite different from that of the repeated-ECS technique. In the latter situation one would predict high defecation scores for all groups. But the inhibition of emotionality measured by defecation scores hint at new and different effects of ECS. It is also suggested that these effects might be separated from the effects of ECS on learning. In view of this, it may be concluded that no proof of the criticisms of the repeated-ECS technique were found for the one-ECS situation when using learning scores as a measure. It may also be concluded that the defecation measure does not support the idea that emotionality would be similar for the two different ECS techniques.

The conclusion that we can draw from this study in view of the literature is that the single-ECS and the sequential-ECS techniques each answer different kinds of questions. Thus, it is not so much whether one approach is supported or not; rather it is a question of which experimental technique is more fruitful in answering the theoretical questions posed.

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ELECTROCONVULSIVE SHOCK, RETROGRADE AMNESIA AND THE SINGLE-ECS METHOD

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B. S., Reed College, 1961

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1964

Criticisms and explanations of the consolidation theory have been concerned with possible confounding of retrograde amnesia (RA) with effects of electroconvulsive shock (ECS) such as avoidance, competing responses, and adaptation syndrome. These factors were evaluated, using the single-ECS method.

Five groups of male albino rats (Sprague-Dawley strain), six rats to a group, were given five escape training trials in a Miller-Mowrer avoidance box. ECS was administered to the rats (a 60 ma. shock for 0.3 seconds through alligator clips attached to the ears). Two groups (performance groups) were given ECS 24 hours prior to training; one group received ECS inside the training box, the other at a location external to the box. Two other groups (RA groups) were given ECS at the external location to the box. The control group received no ECS. All rats were given 10 retention trials 24 hours after training. Analysis of variance procedures were employed to test for the various effects, using errors (unsuccessful escape responses) as the performance measure and defecation as a measure of emotionality.

Results using errors showed that performance groups were not significantly different from controls or from each other. RA groups were not significantly different from each other, but performed significantly poorer than control and performance groups ($p < .01$).

When emotionality scores were analysed, it was found that both the performance groups and the RA groups were significantly different than the controls at the .05 and .005 levels of significance. Thus only the control group had a high rate of defecation.

Since there were no differences between performance and control groups, yet RA and controls did differ, it is suggested that there are no significant physiological effects (general adaptation syndrome) due to ECS, but that RA did indeed occur. Since performance groups did not differ from each other and RA groups did not differ from each other, location of the animal during ECS administration had no significant effect, suggesting that avoidance or competing response effects do not seriously affect performance.

The analysis of the emotionality measures also did not support avoidance or a competing response explanation. It did appear that contrary to these explanations ECS had an inhibitory effect on emotionality.