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A comparison of the effects of two types of electrical stimulation on the white rat: electroconvulsive shock and prolonged electrical shock to the tail.

Sidney Robins

University of Massachusetts Amherst

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A COMPARISON OF THE EFFECTS OF TWO TYPES OF ELECTRICAL STIMULATION ON THE WHITE RAT: ELECTROCONVULSIVE SHOCK AND PROLONGED ELECTRICAL SHOCK TO THE TAIL

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A COMPARISON OF THE EFFECTS OF TWO TYPES OF ELECTRICAL STIMULATION ON THE WHITE RAT: ELECTROCONVULSIVE SHOCK AND PROLONGED ELECTRICAL SHOCK TO THE TAIL

by

Sidney Robins

THESIS SUBMITTED FOR THE DEGREE OF MASTER OF SCIENCE UNIVERSEY OF MASSACHUSETTS

June 1956
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Introduction
An important clinical technique, convulsive shock, has been receiving much attention in animal laboratories in the past fifteen years. Much of the early research which has been summarized by Page (32) and Finger (14) has dealt with the convulsion itself and the environmental and physiological stimuli influencing it (14). Most of the recent work concerns the behavioral effects of convulsions and utilizes electricity, while such convulsive agents as insulin and metrazol are receiving less attention.

The findings generally indicate that a critical number of electroconvulsive shocks (hereafter referred to as ECS) decreases response strength, usually for a limited amount of time. A number of investigators have recently suggested that the General Adaptation Syndrome may mediate the response changes following ECS. This study attempts to throw further light on such an explanation by comparing the effects of a convulsive stimulus with those of a related non-convulsive stimulus.

**Significant Studies**

Most studies have tested the effects of ECS on various types of learned behavior such as habit reversal, simple and complex tasks, inhibited responses, anxiety mediated responses, and "neurotic" or "fixed" behavior. Other studies dealing with physiological effects have dealt with the strength of the convulsing current, resultant emotional states, food intake, and body weight changes.

In those studies concerned with habit reversal two habits learned in succession are followed by ECS, and the result is always a retention of the simpler habit, whether it comes first or last in the sequence.

Typical of this type of experiment is one by Braun and Patton (8) which reports loss of a difficult habit but not of a simple one regardless of which habit was learned first. When the simple habit came first and the
difficult one second, the difficult one was lost as the animal returned to
the simpler after ECS. When the simple one came last the animal continued
with it. Simple and difficult were defined in terms of the number of units
of a maze.

It has also been shown that simple habits are not impaired by ECS,
whereas difficult ones are (11, 20, 42, 44). The first two of these studies,
using complex tasks, found a decrement, whereas the latter two using simple
tasks did not. Russell (39) confirmed these findings by comparing the be-
havior of convulsed rats on the same type of task at two levels of diffi-
culty.

Another group of studies falls into the category of the reinstatement
of an inhibited response (2, 3, 4, 5, 7, 17, 23, 24). In these studies the last
training prior to ECS is a minimum amount of extinction training. Thus
the extinction response, being weakest, was the first to be affected by
ECS. This allowed the original response to become dominant.

A series of studies by Hunt, Brady, and coworkers have indicated that
a specific emotional response ("anxiety") was decreased by ECS (24), and
that the overt response could be entirely removed for a period of time if
the response strength was not too high (3, 24). They have also shown that
the effects of ECS on the response were temporary. That is, the effects
of 21 ECSs lasted approximately 30 days (23). The response used by Hunt
and Brady was an anxiety motivated response which did not remove or affect
the source of the anxiety. In their studies the rat learned to press a
bar in a Skinner box for water reinforcement. When the habit was stabilized,
emotional conditioning was instituted by presenting a clicking sound during
the bar pressing session for three minutes followed immediately by a momen-
tary shock to the foot. After a few trials, the rat ceased bar pressing
and showed signs of fear during the time the buzzer was on. The ratio of
bar pressing during presentation of the buzzer to bar pressing during a neutral time segment in the box provided a measure of the conditioned emotional response.

Masserman and coworkers, studying "neurotic behavior" in cats, were able to remove experimentally induced inhibitions by ECS (27). It is probable that most of their animals did not build up great response strength after receiving an airblast while eating since very few trials were used to bring about the response of staying away from a goal-box with food in it. One criticism of Masserman's work is that there was no strict adherence to experimental design. Animals were subjected to variables indiscriminately.

Meest and Feldman (13,30) tried to alter "fixated behavior" in rats by the use of ECS. Their usual technique was to produce a response in a discrimination situation (Lashley Jumping Stand) under varying conditions, usually frustration, and then to attempt to change the response by making the opposite choice the rewarded one. ECSs did not significantly alter fixated responses when they were applied between the learning of the response and the attempts at alteration. It is possible that the response strength was too high when developed under frustration, to be affected sufficiently by ECS so that a new response could be made. In a recent study (31) where the ECS was given concomitantly with the acquisition of the original response, the ECS group showed significantly greater alteration of the response than did the control group. It is possible that here, ECS had a chance to affect response strength when it was just above threshold.

There have been claims that regardless of the effects of the convulsion itself, the electric current may produce permanent damage. Bamberg (1) ran a study demonstrating permanent impairment when ECS was applied to immature rats, but the impairment may have been due to the convulsion rather than to
the current. Hayes (16) reasoning that a stronger current might produce
greater brain damage and greater impairment if the current is a factor,
found no differences in impairment as the intensity of the current was in-
creased. Townsend et al (47), in a similar experiment, also found no dif-
ferences resulting from different current intensities. It is possible,
however, that by employing a wider range of current than these investiga-
tors used, differences might be found.

A number of studies have clearly revealed the depressant effects of
ECS on the rat's activity level. The greatest amount of activity reduc-
tion is evident only within 24 hours after the last ECS (46,61).

Duncan (11) in a retention experiment gave his control group shock to
the legs, while the experimental group received the shock on the ears pro-
cucing a convulsion. The experimental group was significantly inferior
demonstrating that the emotional state alone resulting from the shock was
not sufficient to produce the impairment. However, the degree of "emotion-
ality" resulting from a single shock to the feet may not be comparable to
that produced by ECS. Had Duncan produced the same degree of "emotionality", his results might have been different.

A study by Mirsky and Rosvold (29) found that rats on an ad libitum
diet lost body weight and reduced food intake following a ten day series of
ECS. Rats which were kept at 85% of body weight showed a significant in-
crease in hunger following ten ECSs. The increase in hunger occurred de-
spite no significant change in amount of activity. The implications of
these results is that the ECS studies using food reinforcement should
clearly define the feeding conditions for the entire experiment. Better
yet, ECS studies should utilize other types of motivation.

It is difficult to apply directly any of these results to the use of
ECS in removing or alleviating neurotic and psychotic symptoms in humans.
As more data are accumulated, the results on rats and on humans should merge into a systematic and applicable theory. The data presently available have added to the knowledge of the relationships of ECS to an organism's behavior and the mechanisms whereby responses may be altered. Much clarification is still needed.

**Theoretical Considerations**

A psychogenic theory which hypothesizes that the decrement is based on fear generalized from the situation in which ECS is administered, is refuted by Braun et al (9). Neither do the results of Duncan (11) support this theory.

Several physiological hypotheses have been advanced as to the nature of the mechanisms underlying the response decrement resulting from ECS. Among them are: damage to the central nervous system, changes in the autonomic nervous system, physiological debilitation, creation of a specific humoral substance in the brain, and a systematic stress theory.

A review of the evidence (9) reveals no clear cut results supporting the specific damage hypothesis. Studies where damage is found are explained by Wilcox (50) who feels that the damage is caused by the use of more current than is necessary for ECS to be effective.

Several studies indicate that the effects of ECS may be more a function of autonomic nervous system involvement than involvement of the central nervous system. Rosvold et al (57,38) have demonstrated functional changes in the adrenal cortex. Gellhorn and Kessler (18) have also demonstrated disturbance of adrenal functioning following ECS, while Hoyt and Rosvold (21) have found changes in body temperature.

A good deal of evidence has been accumulated to show that the convulsion and not the convulsing agent is responsible for the effects found. Some of these studies have found that when the convulsion is prevented by
anesthetization, impairment does not occur (25,33,43,47). Others have shown that the same impairment will occur regardless of the convulsing agent (6,26).

McCannies (23) advocates an explanation in terms of peripheral rather than central factors. He hypothesizes that the ECS decrement is a function of general debilitation.

Cerletti has recently conducted experiments (10) in which the brains of convulsed animals were reduced to a fluid which was found to benefit manic-depressive patients and also slow down the progress of fatal diseases in animals. From these results he concluded, "...I felt I could state that following repeated electroshocks 'highly vitalizing substances with defensive properties' are formed in the brain" (p.209). He called these substances acro-agonines. No biochemical analysis of this brain fluid has yet been made. Cerletti does not believe that the vital substance is ACTH as this latter substance has not proved effective in treating mental patients.

An elaborate stress theory which a number of investigators have referred to (2,33,34,35,43) was developed by Hans Selye (41). Selye claims that any stressor applied at a constant rate will result in the General Adaptation Syndrome (herein referred to as GAS). The three stages are the alarm reaction, the resistance stage, and the exhaustion stage leading to death. The alarm reaction is the sum of all non-specific phenomena elicited by sudden exposure to stimuli to which the system is not adapted. The alarm reaction is divided into the shock stage (characterized as passive and resulting in such physiological signs as hypothermia, hemoconcentration, and depression of the nervous system) and the countershock stage (characterized by manifestations of defense such as adrenal cortical enlargement and increased production of corticotrophin and corticoids.)

Upon prolonged exposure the organism adapts to the stressor. This, the resistance stage, is characterized by the sum of all the non-specific reactions constituting the adaptation. The adaptation seems to be acquired at
the expense of weakened resistance to other stressor agents.

The resistance stage merges gradually into the exhaustion stage as the organism expands its energy, and finally it dies. Various physiological measures taken during the progression of the syndrome all result in approximately the same curve as shown in Figure 1. With respect to the physiological reactions there is usually an initial drop during the alarm stage followed by an upswing which levels off through the resistance stage, and finally drops off completely in the exhaustion stage.

![Diagram of physiological reaction stages](image)

**Fig. 1.** Typical curve describing the stages of the general adaptation syndrome proposed by Selye (41, p.4)

Townsend et al (48) experimenting with RCS on rats noted that their animals dropped off in weight during the first few convulsions and finally levelled off at about the tenth daily convolution. They further noted that the incidence of fractures was greatest at about the tenth convolution, and suggested that RCS may act as a stressor.

Stem (46) specifically investigated weight changes during a series of 16 daily RCSs. The results were not clear for two of his groups which were under partial food deprivation (apparently also a stressor). The
third group which was on an ad libitum food and water schedule revealed a typical GAS curve. From these and unpublished studies, he estimated that with one daily convulsion the syndrome runs the following course: shock stage, days one to five; countershock, days six to fifteen; resistance, days sixteen to ninety; and exhaustion, days ninety to death.

Riess, who was the first to interpret the effects of MCS in terms of the GAS (36), refers to one of his studies (34) in which rats receiving more than 100 MCSs revealed behavioral and food intake curves typical of the GAS.

The most convincing data suggesting that MCS may function largely as a stressor comes from a study by Rosvold et al (37). They gave a ten day series of MCS to a group of anesthetized rats while another group was convulsed under normal conditions. A third group received anesthesia only. Animals which were convulsed showed adrenal cortex hypertrophy significantly greater than controls or animals receiving anesthesia only. They also found that animals which were convulsed showed significant hypertrophy over animals in whom the convulsion was prevented by anesthesia. They suggested that since there are coincident changes in the rats' behavior and physiological condition following MCS, the behavior changes may be mediated by the physiological condition.

It can be seen that some recent theory, stemming from animal studies, emphasizes physiological changes in explaining the effects of MCS. The exact nature of these changes and their relationship to behavior is yet to be determined. It should be revealing, therefore, to compare directly the behavioral concomitants of MCS with those of the GAS.
The Experimental Investigation
Statement of the Problem

This investigation attempts to bring together data, both behavioral and physiological, toward a unified explanation of the effects of electroconvulsive shock. More specifically, the effects on the white rat of intense non-convulsive electrical stimulation applied to the tail are compared with those of convulsive stimulation. Thus, a group receiving convulsions, a group receiving intense electrical stimulation to the tail (stress), and a control group will be compared with each other on their retention of maze learning.

A consideration of the problem presents three testable hypotheses:

I. Both the ECS and the stress groups will show a response decrement significantly greater than the control group.

II. There will be no significant difference in the degree of decrement between the ECS group and the stress group.

III. A physiological measure (weight change) will show correlation with the response measure.

II Apparatus and Subjects

A. Apparatus

A five choice-point water maze based on the Lashley III design and patterned after one described by Townsend et al (43) was used for the learning and retention problem. The maze consisted of a copper tank with 1/16th inch sheet metal partitions (Figs. 2 & 3). The entire interior of the tank was painted with non-toxic black asphaltum paint. Retracing doors were manually operated by black nylon string pulls running through eyelets to the control panel at the front of the tank. The doors slid sideways, to and fro from the center. Placed in front of the tank, a glass screen prevented the experimenter from being visible to the animals from any portion of the maze except the starting chamber which was covered
FIGURE 2  FRONT VIEW OF APPARATUS

LIGHT SHADE
ROOFING PAPER
GAUZE SCREEN
DRAW STRINGS
WATER LEVEL
STARTING CHAMBER
TANK
FIGURE 3. DIAGRAM OF WATER MAZE
by a black door. The effectiveness of the screening was increased by keeping the room illumination at a minimum. A shaded, diffused, hundred-watt bulb was suspended four feet above the geometrical center of the tank and within the confines of the shading. The shading, which confined the light to the tank, consisted of heavy black roofing paper suspended from the light shade, tent-like, and fastened to the sides of the tank. Tank water was replaced as needed with fresh water.

Cylindrical holders, 2½ inches in diameter and ten inches long, constructed of 3/8th inch wire mesh were used to confine the rats during the tail shock procedure. The electrical stimulus originated from an electronic device designed to provide a constant current regardless of the resistance involved. The current was delivered through two spring electrodes curved to fit snugly over the rats' tails. Skin resistance was brought to a minimum in all electrical procedures by application of EEG paste underneath the electrodes. A stop watch was used to time the maze trials. The ECS stimulus was provided by a modification of the Pittsburgh Electroshock Apparatus (40).

The water maze was chosen for the behavioral measurements because of the large number of successful experiments which have been conducted with it, and because it provides a source of motivation which, unlike hunger, is constant throughout the treatment period. Electric shock, applied non-convulsively, seemed to be the best stressor for comparison as it was similar in nature, being electrical, to the convulsing stimulus.

E. Subjects

Forty-six male albino rats ofWiki strain from the Hatch Laboratory

---

*The constant Current Electronic Stimulator, Model 233, C. J. Applegate & Co., 1815 Grove St., Boulder, Colorado
of the University of Massachusetts were used as the subjects for this experiment. Their ages ranged from 110 to 130 days. The animals were housed in individual bucket cages.

III Procedure

Table I below, presents an outline of the experimental procedure. Forty six rats learned the five unit water maze to criterion. They were then divided into three equated groups. Group I, hereafter referred to as the ECS group, received a series of twenty ECSs. Group II, hereafter referred to as the stress group, underwent twenty periods of tail shock. Group III, the control group, was given a series of twenty pseudo ECSs. After the last experimental treatment was given, retention of the original learning was determined by having each rat swim through the maze until it again reached criterion.

Table I

<table>
<thead>
<tr>
<th>Group</th>
<th>ECS</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>Preliminary Handling</td>
<td>Preliminary Handling</td>
<td>Preliminary Handling</td>
</tr>
<tr>
<td>B.</td>
<td>Preliminary Training</td>
<td>Preliminary Training</td>
<td>Preliminary Training</td>
</tr>
<tr>
<td>C.</td>
<td>Learning</td>
<td>Learning</td>
<td>Learning</td>
</tr>
<tr>
<td>D.</td>
<td>Electroconvulsive Shock</td>
<td>Tail Shock</td>
<td>Pseudo Electroconvulsive Shock</td>
</tr>
<tr>
<td>E.</td>
<td>Retention</td>
<td>Retention</td>
<td>Retention</td>
</tr>
</tbody>
</table>

A. Handling and Weight Recording

All rats were handled daily for the first week. Handling consisted of the manipulations necessary to remove them from the cages and weigh them
plus fifteen seconds of back stroking while held in the cupped hand to accustom them more rapidly to handling.

B. Preliminary Training

At the end of this time each rat was given twenty five orientation trials in groups of five trials each, 12 hours apart to familiarize him with swimming and escaping from the water. An orientation trial consisted of gently placing the rat into the water at the end of the alley opposite the escape platform and so that he faced it (point A, Fig. 3). The animal was allowed to swim until it reached the escape platform and walked out of the water. Fifteen seconds of rest was allowed between a rat's orientation trials. The retracing door at the last choice point remained closed during the orientation trials, so that the orientation swimming was confined to the final alley of the maze.

C. Learning Trials

Twelve hours following the 25th orientation trial, the learning trials were started. A learning trial consisted of gently placing the rat, face forward, into the water of the starting chamber and allowing it to swim through the maze until it reached the escape platform. The retracing doors were closed at each choice point after the rat passed through to prevent backtracking. Turns into a cul de sac, of the full length of the body excluding the tail, were recorded as errors. Swimming time was taken from the rat's release in the starting chamber to his complete exit, excluding the tail, from the water. Each rat was given three learning trials a day, eight hours apart until three consecutive traversals had been made with no more than five errors. The rats were dried with a towel before being returned to their cages. The water in the maze was kept at room temperature (21 to 23 degrees centigrade).
Throughout the experiment, each rat’s weight and the weight of the food consumed was recorded at noon. Food consisted of the standard laboratory diet of Purina Fox Chow supplemented twice weekly with lettuce. An ad libitum food and water schedule was in force throughout the experiment. Experimental and control animals were put through trials in random order to minimize differential treatment.

D. Experimental Treatment

As each rat reached the criterion of learning, it was placed, following a counterbalanced (ABCCBA), into one of three groups. Thus rats were placed into the three conditions of the experiment as follows: first rat into Group I, second rat into Group II, third rat into Group III, fourth rat into group III, fifth rat into group II, sixth rat into Group I, etc. When more than one rat reached criterion at the end of any one trial they were placed in the three groups so as to yield minimum differences between the mean weights of the groups. In this way the groups were equated for learning and weight scores.

Each rat was started on the experimental treatment sixteen hours after its last learning trial. Twenty convulsions were produced in each of the rats in the ECS group (Group I), one every twelve hours, by a 50 milliamperes current at 110 volts applied for one second through clip electrodes placed on the rat’s ears. Electrode paste was placed in the cups of the electrodes to insure a good electrical contact.

The animals in the stress group (Group II) were given twenty periods of tail shock, at 12 hour intervals. Each period lasted twenty minutes, and shocks at the rate of two pulses per second were administered. A current of 500 microamperes at 110 volts was used. The animals were placed face forward, into the cylindrical holders with only their tails protruding
FIGURE 4. RAT HOLDER AND STAND WITH HOLDERS
(Fig. 4), and were kept from escaping by the use of sixteen pennyweight nails pushed through the wire mesh. The electrodes were attached to the rats' tails and were connected in series to the stimulator (Fig. 5). They were placed on the tail, one inch apart and two inches from the base of the tail. The holders containing the rats were suspended into a cardboard carton. (Fig. 4)

The control group (Group III) was given a series of twenty pseudo shocks, one every twelve hours. This consisted of placing electrodes on the rat's ears and the ES machine's switch thrown, but with the power supply turned off.

E. Relearning Trials

Forty eight hours after its last experimental treatment each rat was returned to the water maze for its retention trials. The rats were again allowed to swim on the same schedule as before until they reached the original criterion of no more than five errors in three trials.

F. Adrenal Weights

A physiological measure of the SAD, in addition to weight, became available at the end of the experiment. This was the weight of each animal's adrenal glands. Three days after the last rat's last criterion trial, the animals were sacrificed and their adrenals removed and immediately weighted on a laboratory balance.
Results

A. Quantitative

The results consisted of learning and relearning scores for trials, errors and time to reach criterion, and the daily body weights, post mortem adrenal weights, and the weights of the daily food intake for each animal. The relearning scores were subtracted from the learning scores and a constant added so that all of the resultant retention indices were positive. Fisher's small sample t test (16, p. 228) was used to determine the reliability of the differences between the retention indices of the three groups, and to compare their original learning scores. The adrenal weights were also converted into indices by taking the quotient of the adrenal weight of an animal divided by his preexperimental body weight and multiplying this quotient by 1,000.

The body weight change scores for each animal were determined by subtracting the weight at the end of the experimental treatment period from that at the beginning and adding constants to make all of the scores positive. Both the adrenal indices and the body weight scores were treated by Fisher's small sample t test for differences between the groups. The extent of correlation between weight change and each of the retention scores, and also between adrenal weights and each of the retention scores was determined for all three groups by Pearson's product moment correlation method (16, p. 160).

As half of the animals in the SOS group revealed injuries, comparisons were made between the performances and the adrenal indices for the injured and the uninjured animals in this group to see if they constituted a homogeneous group in relation to the variables being measured. In table 7 comparisons are shown for the injured and the uninjured animals in the SOS
group. The injured animals were ones which had developed one or more paralyzed paws after the ECS treatment, whereas the uninjured animals showed no obvious injury. The t tests revealed no significant differences between the injured and the uninjured animals with respect to the following measures: trials (relearning), weight gain and adrenal weight indices. Since the injuries did not affect these important variables, the group as a whole was used in making comparisons with other groups.

Table 2 presents a comparison of learning scores within the three groups in terms of trials, errors, and time scores. The t test results for comparisons between these scores are shown in Table 3 and they reveal no significant differences between experimental and control groups for any of the scores. Because the groups had been equated for trial and error scores and in view of the results of the t tests, it is assumed that they were of equal learning ability for the purposes of the experiment.

The statistical comparisons between all groups for trials-to-criterion retention indices are given in Table 4. The ECS group revealed significantly poorer retention at better than the one percent level of confidence, than both the control and the stress groups. There was no significant difference between the control and the stress groups, however.

The comparisons of error retention indices, shown in Table 5, give the same results: the ECS group was significantly poorer than both the controls and stress groups at better than the one percent level of confidence. As before, no significant difference occurs between the control and the stress groups.

In Table 6 similar results are found for comparisons of the time retention indices. Again, the ECS group showed less retention than the stress and control groups, however the difference was significant only at the five percent level of confidence. As before, no significant difference resulted
Table 2

Comparison of original learning between experimental and control groups in terms of mean trials, errors, and time.

<table>
<thead>
<tr>
<th></th>
<th>EOS</th>
<th>Stress</th>
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<tbody>
<tr>
<td>N</td>
<td>16</td>
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<td>15</td>
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<td>Mean Trials</td>
<td>4.75</td>
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<td>4.73</td>
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<td>2.00</td>
<td>2.32</td>
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<tr>
<td>Mean Errors</td>
<td>27.2</td>
<td>27.7</td>
<td>29.1</td>
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<tr>
<td>Sigma</td>
<td>10.72</td>
<td>11.65</td>
<td>11.97</td>
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<tr>
<td>Mean Time</td>
<td>269.00</td>
<td>302.00</td>
<td>361.20</td>
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<td>Sigma</td>
<td>146.60</td>
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<td>197.87</td>
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Table 3

The t-test results for original learning scores between experimental and control groups in terms of mean trials, errors, and time.

<table>
<thead>
<tr>
<th>Groups</th>
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<td>Control vs. Stress</td>
<td>49.20</td>
<td>.77</td>
</tr>
</tbody>
</table>

*None of the t's were significant at the 5% level of confidence.
<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference between means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGS vs. Stress</td>
<td>4.32</td>
<td>3.31</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>MGS vs. Control</td>
<td>4.66</td>
<td>3.33</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Control vs. Stress</td>
<td>0.33</td>
<td>0.33</td>
<td>—</td>
</tr>
</tbody>
</table>

* The retention index is the learning score minus the relearning score plus a constant to make all scores positive.
Table 5

A comparison of retention indices*, for errors to criterion, between experimental and control groups.

<table>
<thead>
<tr>
<th></th>
<th>BOS</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>22.19</td>
<td>41.27</td>
<td>43.87</td>
</tr>
<tr>
<td>Sigma</td>
<td>13.08</td>
<td>11.40</td>
<td>14.93</td>
</tr>
<tr>
<td>N</td>
<td>16</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

* The retention index is the learning score minus the relearning score plus a constant to make all scores positive.
Table 6

A comparison of retention indices for time to criterion, between experimental and control groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference between means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG vs. Stress</td>
<td>15.93</td>
<td>2.35</td>
<td>.05</td>
</tr>
<tr>
<td>Stress vs. Control</td>
<td>19.39</td>
<td>2.65</td>
<td>.05</td>
</tr>
<tr>
<td>Control vs. Stress</td>
<td>3.46</td>
<td>0.46</td>
<td></td>
</tr>
</tbody>
</table>

* The retention index is the learning score minus the relearning score, plus a constant to make all scores positive.
Table 7

A comparison of injured and uninjured* animals in the ECS group.

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Uninjured</th>
<th>Dif. bt. means</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Mean Trials Retention indices</td>
<td>10.63</td>
<td>7.00</td>
<td>3.63</td>
</tr>
<tr>
<td>Sigma</td>
<td>2.83</td>
<td>4.30</td>
<td></td>
</tr>
<tr>
<td>Mean weight change indices</td>
<td>23.40</td>
<td>29.50</td>
<td>6.10</td>
</tr>
<tr>
<td>Sigma</td>
<td>17.02</td>
<td>10.03</td>
<td></td>
</tr>
<tr>
<td>Mean Adrenal Weight indices</td>
<td>41.60</td>
<td>47.62</td>
<td>6.02</td>
</tr>
<tr>
<td>Sigma</td>
<td>24.97</td>
<td>21.75</td>
<td></td>
</tr>
</tbody>
</table>

* Injured animals had one or more paralyzed paws whereas uninjured animals showed no obvious injury.
between the stress and control groups.

For all three retention indices, therefore, the ECS group revealed a decrement in retention when compared with the stress or control group, whereas no significant differences occurred between the stress and control groups.

Differences, all better than the one percent level of reliability between body weight changes, are shown in table 6. The control group gained most in weight, the stress group least, and the ECS group, the least.

In table 9 it is seen that the daily food intake means of the three groups are significantly different from each other. All were beyond the one percent level of confidence. The control group consumed the most, the stress group least, and the ECS group the least amount of food. The daily food intake curves are presented graphically in Figures 6 and 7 respectively.

Table 10 reveals a significant difference between the mean adrenal weight indices of the control group and the ECS group, at better than the five percent level. The stress group did not differ reliably from either the control group or the ECS group on this measure. The control group had the lowest adrenal weights, the stress group higher weights, and the ECS group the highest adrenal weights.

Table 11 presents the Pearson product moment correlations between weight and each of the three retention indices for all groups. According to the Tables of Significance in Edwards (12, p. 408) none of these coefficients is significantly different from zero.

In table 12 are the Pearson product moment correlations between adrenal weight indices and each of the three retention indices for all groups. From the same tables of significance it is seen that only the correlation between the adrenal indices and the error score indices for the stress group in significant and this is at the five percent level.
Table 3

Comparison of body weight gain in terms of standard scores* from the beginning to the end of experimental treatment for experimental and control groups.

<table>
<thead>
<tr>
<th></th>
<th>EGS</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>38.93</td>
<td>47.93</td>
<td>67.95</td>
</tr>
<tr>
<td>Sigma</td>
<td>13.99</td>
<td>13.56</td>
<td>6.16</td>
</tr>
<tr>
<td>N</td>
<td>16</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Difference between means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGS vs. Stress</td>
<td>19.02</td>
<td>3.73</td>
</tr>
<tr>
<td>EGS vs. Control</td>
<td>29.02</td>
<td>9.51</td>
</tr>
<tr>
<td>Control vs. Stress</td>
<td>20.00</td>
<td>5.26</td>
</tr>
</tbody>
</table>

* Standard scores represent weight gain plus a constant to make all scores positive.
FIGURE 6. MEAN DAILY BODY WEIGHTS
Table 9

A comparison of mean food intake in grams for experimental and control groups during experimental treatment.

<table>
<thead>
<tr>
<th></th>
<th>EGS</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>10.99</td>
<td>16.61</td>
<td>19.19</td>
</tr>
<tr>
<td>Sigma</td>
<td>1.37</td>
<td>2.17</td>
<td>1.55</td>
</tr>
<tr>
<td>N</td>
<td>16</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference between means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGS vs. Stress</td>
<td>5.62</td>
<td>8.36</td>
<td>.01</td>
</tr>
<tr>
<td>EGS vs. Control</td>
<td>8.20</td>
<td>15.19</td>
<td>.01</td>
</tr>
<tr>
<td>Control vs. Stress</td>
<td>2.88</td>
<td>3.66</td>
<td>.01</td>
</tr>
</tbody>
</table>
FIGURE 7. MEAN DAILY FOOD INTAKE

FOOD INTAKE (IN GRAMS)
Table 10

A comparison of adrenal weight indices taken at the end of relearning for experimental and control groups.

<table>
<thead>
<tr>
<th></th>
<th>ECS</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>110.12</td>
<td>100.00</td>
<td>93.20</td>
</tr>
<tr>
<td>Sigma</td>
<td>23.02</td>
<td>18.42</td>
<td>19.68</td>
</tr>
<tr>
<td>N</td>
<td>16</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference between means</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECS vs. Stress</td>
<td>10.12</td>
<td>1.31</td>
<td>--</td>
</tr>
<tr>
<td>ECS vs. Control</td>
<td>15.92</td>
<td>2.75</td>
<td>.01</td>
</tr>
<tr>
<td>Control vs. Stress</td>
<td>6.60</td>
<td>0.83</td>
<td>--</td>
</tr>
</tbody>
</table>

* Adrenal weight index equals 1000 \( \frac{\text{adrenal weight}}{\text{body weight}} \)

Adrenal weights are post-experimental and body weights are pre-experimental.
Table II
Results of Pearson product moment correlations between weight gain in terms of standard scores, and trial, error, and time to reach criterion retention indices.

<table>
<thead>
<tr>
<th></th>
<th>ECA</th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>16</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Weight vs. Trials</td>
<td>.19</td>
<td>.29</td>
<td>.06</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>.26</td>
<td>.25</td>
</tr>
<tr>
<td>Weight vs. Errors</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>.26</td>
<td>.25</td>
</tr>
<tr>
<td>Weight vs. Time</td>
<td>.14</td>
<td>.40</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>.26</td>
<td>.22</td>
</tr>
</tbody>
</table>

None of the correlations are significant at the five percent level of confidence.
Table 12

Results of Pearson product moment correlations between adrenal weight indices and trial, error, and time to reach criterion retention indices.

<table>
<thead>
<tr>
<th></th>
<th>Stress</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td><strong>Adrenal Weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vs. <strong>Trials</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation (r)</td>
<td>.06</td>
<td>.30</td>
</tr>
<tr>
<td>Std.</td>
<td>.25</td>
<td>.24</td>
</tr>
</tbody>
</table>

| **Adrenal Weight** |        |         |        |
| Vs. **Errors**    |        |         |        |
| Correlation (r)   | .04    | .58*    | .20    |
| Std.              | .26    | .17     | .26    |

| **Adrenal Weight** |        |         |        |
| Vs. **Time**      |        |         |        |
| Correlation (r)   | .27    | .15     | .26    |
| Std.              | .24    | .26     | .25    |

* Significant at the 5% level of confidence.
Eight of the sixteen animals in the ECS group were found to have one or more paralysed paws after coming out of the post-shock coma. Although this interfered with their walking, it constituted no hindrance in swimming the maze. This was verified by the lack of significant differences among the comparisons shown in Table 7.

During the experimental procedure the animals in the ECS group showed exaggerated startle reactions. They also urinated, defecated and tried to escape when removed from their cages to be given ECS. Their bodies had a chronic tenseness or stiffness to the touch. The animals in the stress group became very docile and offered no resistance to being put into their holders for the tail-shock procedure. The control animals showed no obvious behavioral or physiological change. The behavior of the ECS animals is consistent with the findings of Hunt et al (23, p. 596) who report that: "Treated animals consistently show signs of heightened irritability and emotionality. . . . ."

Discussion

A. The Results in Terms of the Hypotheses

Contrary to hypothesis I, a comparison of retention indices uniformly revealed no differences on any of the retention measures between the stress and control groups. The findings of significant differences with respect to retention measures between the ECS and control groups were in agreement with hypothesis I. Contrary to hypothesis II the ECS and stress groups differed significantly on all three retention measures. Hypothesis III was not supported as there was no correlation between weight and any of the three retention measures. Nor were any of the correlations between adrenal indices and
the retention measures significant with one exception. This was between the adrenal indices and the error score retention indices for the stress group and was significant at only the five percent level.

B. Interpretation of the Physiological Measures

Before the retention results are discussed it would be well to explain the results of the physiological measurements. It must be remembered that one of the purposes of this experiment was to determine the effects on a learned response of ECS and of tail-shock while holding physiological changes as constant as possible. Since both the ECS and the stress groups differed significantly from the controls on the weight measures, it can be concluded that one of the results of ECS or prolonged tail-shock is either to prevent normal weight gain or to produce weight loss. However, in this study the ECS and stress groups also differed from each other on the weight measure. Apparently then, these two types of electrical treatment as used here did not produce an equivalent physiological effect. This was further demonstrated by the comparison of adrenal indices means which were similar to the means for body weight. That is, the greatest difference was found between the control group and the ECS animals and a lesser difference between the control group and the stress animals. These changes in adrenals, however, were of a sufficiently small magnitude so that only the ECS and not the stress group differed significantly from the control group.

It had been hypothesized from a pilot study (36) that the amount of ECS and tail-shock used in this study would produce similar physiological results, but this did not occur. A likely explanation of the lack of similar results follows. The only available means of equating groups physiologically at the time the study was undertaken, was by amount of weight loss. The data of the prior pilot study had indicated that over a period
of ten days, twenty minute periods daily of tail-shock produced as much
weight loss, and at the same rate, as one daily administration of ECS.
In the current study however, two ECSs and two twenty minute periods of
tail-shock were administered daily for ten days. The resultant mean weight
losses were significantly different. It appears, then that the pilot re-
results were not truly indicative of the effects of the two types of shock
on weight loss, or that the equivalence may hold only for the conditions
of one daily administration.

C. Interpretation of the Retention Measures

A decrement in retention of the ECS group as compared with the re-
tention of the control group is in keeping with the general findings of
other ECS studies dealing with a complex learning task. An interpreta-
tion of the stress group's results is more problematic. It was hypo-
thesized that if they underwent similar physiological changes to the ECS
group, as represented by weight loss and adrenal hypertrophy, they would
suffer the same degree of retention decrement. Neither similar physio-
logical changes, nor similar retention changes resulted between the ECS
and stress groups. The stress and control groups did differ on one
measure, weight, and a suggestion of a difference (not reliable) was
present for the adrenal weight indices. Why then did not their perform-
ance differ from the controls? Two likely but alternate explanations fit
the retention data of the three groups:

1. ECS affects learned behavior directly through some electrical
and/or physiological reaction taking place solely in the
brain. The physiological reactions such as weight and
endocrine changes are secondary effects and do not mediate
the changes in learned behavior.

2. The effects of ECS on learned behavior are mediated through
these physiological reactions which constitute the GAS and
are a result of the stress produced by the convulsion.
(It follows that if such changes could be produced with nonconvulsive stimuli, learned behavior would be affected as though with ECS.)

Because of the failure to equate the physiological reactions of the stress and ECS groups neither explanation is supported by the data of the study. However the data can fit into both explanations.

The first explanation involves detailed studies of brain tissue changes. According to Braun et al (9, p. 101) "...a number of reports in the literature on the effects of electroshock convulsions upon the morphology of the central nervous system have failed to find evidence of alterations in brain tissue". They also state that alterations in brain tissue would not alone be conclusive. It would also have to be shown that there was a correlation between the damage and learned behavior.

The second explanation which involves endocrine changes as the important factor is best expressed in terms of Selye's General Adaption Syndrome. The ECS groups seem clearly to have undergone the GAS. According to Turner (49, p. 191), "The most prominent morphologic and functional changes which occur during the S-A-S are (1) enlargement of the adrenal cortex with an increase in the release of cortical steroids. . .". It was found that the ECS animals here as well as in Hoyos's study (37), showed adrenal weights significantly larger than the controls. The decrement in their retention could, therefore, conceivably be mediated by the GAS.

The physiological condition of the stress group was not as clear in terms of the GAS. Although these animals showed weight loss significantly greater than the control group, the loss was however significantly less than that of the ECS group. Their adrenal weight scores were in the right direction, but did not differ significantly from the control group. Neither did they differ from the ECS group.

It is possible that the amount of tail-shock given was not sufficiently stressful to cause the animals to display the GAS. A more likely
explanation is that the stress animals revealed the GAS but at a slower rate than the ECS group did so that they were in an earlier stage of the syndrome. How do the physiological data fit this latter hypothesis? The weight measures revealed significant differences between the ECS and control groups. Apparently then on the basis of this measure both groups progressed into the syndrome but the ECS group progressed further. The adrenal weight changes revealed the same relationships between groups except that only the difference between the ECS and the control group was significant. In keeping with the hypothesis that the stress group was not as far along the GAS as the ECS group it could be said that the adrenal indices differences would show the same significance that the weight measures did if it were not for the fact that the adrenal changes were of lesser magnitude.

If the hypothesis is correct that both the ECS and stress groups showed signs of the General Adaptation Syndrome but that the ECS group was in a more advanced stage of the syndrome, how can the retention measures, particularly the lack of decrement for the stress group, be accounted for? One possibility is that there is a critical point during the progression of the GAS before which no behavioral changes are mediated. A more likely explanation is that the physiological changes which occur during the GAS affect behavior differentially as the syndrome progresses. Such an explanation can best be understood of Gelye's data on the general physiological changes of the GAS are interpreted in terms of drive state i.e., the drive state which is a factor in performance is determined by the physiological condition of the organism. To understand this fully a discussion of the relationship between drive state and performance is necessary.

The notion that beyond an optimal point further increase in drive level is detrimental to the "correct response" is widely held but rarely
explained theoretically. Hebo (19) presents such an explanation in terms of neural functioning. He conceptually depicts the relationship between response and drive state in the following terms. Sensory events are seen as having two different effects, the cue function and the arousal function. The former guides behavior whereas the latter provides an energizing background for it. In a manner of speaking the arousal function "runs the motor" while the cue function "does the steering". He further points out: "Arousal in this sense is synonymous with a general drive state, and the conception of drive therefore assumes anatomical and physiological identity". (19, p. 260).

![Graph](image_url)

**Figure 8.** Relationship between arousal and cue functions. (Adapted from Hebo, 19, p. 260)
Webb considers the arousal function, at a neural level, as cortical bombardment (abscissa in fig. 6). Up to the optimal point, cortical bombardment (drive) results in negatively accelerated cue function. Beyond this point increasing bombardment results in positively decelerated cue function. He assumes that cortical bombardment facilitates synaptic function but that beyond the optimal point it interferes with "the delicate adjustments involved in cue function, perhaps by facilitating irrelevant responses". (p. 243).

In Hullian theory, performance (i.e. excitatory potential of the correct response) increases with increase in drive (22). Hebb suggests that this relationship holds only up to an optimal level of drive. Beyond this point additional drive may be detrimental to the correct response as a result of a "cortical overloading" factor. Both Hullian theory and that of Hebb are consonant with an explanation that the detrimental factor may result from additional competing responses being brought above threshold as drive increases.

With these considerations in mind an interpretation is possible of the retention data in terms of the following relationship between the progression of the GAS and drive level. If it is assumed that drive level follows along with the other physiological reactions constituting the GAS, the groups in this study would fall at the points indicated in Figure 9. The curve shows a slight decrease in drive during the shock phase of the alarm stage followed by a return to normal and beginning of an upswing during the countershock phase. The maximum is reached during the resistance stage and drive remains at this level until it falls off through the exhaustion stage reaching the zero point at the death of the organism.
Figure 9. The theoretical positions of control, stress, and ECS animals on the curve depicting the hypothetical drive level during the progression of the GAS.

If both the ECS group and the stress group are considered as being in the GAS, it must be remembered that the data indicated the ECS group to be further along the GAS than the stress group. Furthermore, Stern (43) suggests that following approximately the 16th convolution, animals enter the resistance stage of the GAS. If point OPT of Figure 9 is taken as the optimal level of drive for the production of the correct maze response, it is seen how the ECS group falls beyond this point. The stress group although having progressed through the first stage of the syndrome, could still be at the normal drive level. The control group, of course, would be at the normal drive level. This would account for the obtained retention data. The control and stress groups being at the same drive
level, even though they had not undergone the same physiological changes, would be expected to have similar performances since all other factors were kept constant. The 60G group, having undergone physiological changes, which put them beyond the optimal drive level, would be expected to reveal a decrement in performance.

D. Relation of Physiological to Performance Measures

It seems from the results that there is not a direct relationship between retention and either of the two physiological measures investigated (body weight and adrenal gland weight). Only one of the sixteen correlations was significant, that between the adrenal indices and the error score retention indices for the stress group, and it was significant at only the five percent level. In view of the large number of correlations computed between the physiological and performance measures, it is hardly meaningful that one was significant at the five percent level.

Should the decrement following 60G be a central i.e. cerebral rather than a peripheral phenomenon there would, of course, be no correlation. If the behavioral effects of 60G are a function of the GAS, it would be expected that the physiological changes constituting the GAS would be correlated with behavioral changes. The lack of correlation between retention indices and body weight measures could be a result of the body weight changes not directly representing the effects of physiological change on drive state. The correlations between retention indices and the adrenal gland weights are generally higher than those between retention indices and the body weights. This trend suggests that the former might show more significant correlation than the latter if the number of subjects were large enough. Physiologically it would be expected that adrenal function would affect behavior more than body weight.
Unfortunately it is not possible to measure directly the extent of change in an animal's adrenal glands as a result of the treatment given it. The adrenals can only be weighed once. The change must be estimated from a ratio of the weight of its adrenals to the weight of the animal and hence the variance is increased so that a true correlation would always be underestimated. Then too, there probably are physiological changes besides those in the adrenals which affect the ultimate drive state, so that even the true correlation would be well below unity and would require a fairly large number of subjects before significance was achieved.

The indications of a GAS-drive state hypothesis for further studies would involve the following variables. It would be desirable to vary the number of ECSs from zero to the number required to put an organism into the resistance stage of the GAS. Physiological and performance measures could then be plotted and checked for correspondence with the hypothesis. Or a stressor other than a convulsive agent could be used to produce the GAS and the physiological and performance measures for this condition could be plotted and checked for correspondence with those found for ECS.

The chief aim would be to test for correspondence between the physiological changes of the GAS, those occurring during an ECS series, and the behavioral changes following ECS administration.

**Summary**

Forty-six male albino rats were trained to a criterion of no less than three errors in five trials in a five choice-point water maze. They were then placed into three groups, equated on the basis of trials to criterion, and weight scores, and the groups were treated differentially as follows. Animals of the ECS group were given a series of twenty electro-convulsive
shocks, those of the control group received twenty pseudo shocks, and those of the stress group were given twenty, twenty minute periods of intense pulsing shock (nonconvulsive) to the tail. The animals were then tested for retention of their maze learning by having them again re-satisfy the same criterion of mastery. The differences between groups for trials, errors, and times to reach criterion scores were compared statistically. Comparisons were also made for changes in body weight, adrenal gland weight and food intake for each group. The weight change and adrenal index scores were then tested for correlation with each of the retention scores for the three groups. The comparisons revealed a decrement in the maze retention of the ECS group and none for either the stress or control groups. The experimental treatments resulted in changes in weight and food intake significantly different between all three groups, but no meaningful relationship was found between weight changes and any of the retention measures. The results of the ECS and control groups were consonant with those of studies by other investigators. Since the amount of tail-shock used did not produce physiological stress reactions in the stress group of equal magnitude to those produced by the convulsive procedure in the ECS group, it could not be determined whether the kind of stimulation or the physiological reactions resulting from the stimulation is the important factor in producing a retention decrement. The results of this study fit both a central explanation emphasizing changes within the brain and a peripheral one emphasizing changes in the whole body. This latter explanation was discussed in terms of an hypothesis relating the General Adaptation Syndrome of Selye, the physiological effects of electroconvulsive shock, and theory regarding the relationship of drive state to performance. Studies to test a GAS-drive state hypothesis were indicated.


3. ______________, The effects of ECS on a conditioned emotional response: the significance of the interval between the emotional conditioning and the ECS, J. Comp. and Psychol., 1952, 45, 3-13.


5. ______________, A further demonstration of the effects of ECS on a conditioned emotional response, J. Comp. and Physiol. Psychol., 1951, 44, 204-205.


48. Wilcox, P. K., Brain facilitation, not brain destruction, the aim in electric shock therapy., Dis. Nerv. Syst., 1948, 7, 201-204.

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I am also indebted to Dr. Albert E. Gose for his suggestions concerning statistical procedures and to Mr. Joseph Mach for his aid in constructing and assembling the apparatus.
Approved by

[Signatures]

Date: May 25, 1935