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THE EFFECTS OF ELECTROCONVULSIVE SHOCKS ON RETENTION OF A SIMPLE VISUAL PATTERN DISCRIMINATION HABIT IN THE ALBINO RAT

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by

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TABLE OF CONTENTS

Introduction

It is common knowledge that several centuries ago severe physical and mental maltreatment were thought to act as a cure for persons with mental disorders. Many mental cases were thrown into dungeons and prisons where they were chained and beaten, and it was common practice to administer bleeding treatments and torture to the mentally derranged. With the beginning of the 18th century more humane treatment was shown towards mental patients. There slowly came about a realization that the affliction from which they suffered was not due merely to their inability to maintain their good sense and reason, but to factors over which they had little or no control. Since that time a program of better and more humane treatment has been the goal. With the advent of relatively widespread public education concerning mentally ill persons, a more scientific and objective attitude developed towards the mentally ill and their treatment.

Today shock treatment is one of the most widely prescribed forms of therapy in use for psychotics. Some consider shock treatment a misnomer, for if properly handled the patient suffers no hemorrhage or shock in the usual medical sense of the term. The three main forms of shock therapy are insulin, metrazol, and electric.

Insulin shock therapy was first used by Manfred Sakel in 1933. He discovered that some of the patients who received insulin treatment lost their psychotic symptoms. He attributed the remission of symptoms to the effect of the coma, which in turn was produced by a hypoglycemic reaction in the organism.

About the same time that Sakel was experimenting with

insulin von Meduna was producing convulsions in schizophrenic patients with metrazol. The reasoning behind the treatment was the medical belief that schizophrenia and epilepsy rarely occured together; thus, in some way, the convulsions that epileptics manifested protected them from schizophrenic manifestations. With this reasoning in mind he proceeded to convulse schizophrenic patients and observed a remission of symptoms in certain of the patients. Objections have been raised to the widespread use of metrazol to produce convulsions on the grounds that fractures and other physical disorders may result and that the patient is usually aware of intense anxiety feelings before he loses consciousness.

In 1937 Cerletti and Bini succeeded in passing an electric current through the brain, first in animals then in psychiatric patients, to produce a convulsion. This method has now been adapted widely by many psychiatrists. There are several reasons for favoring this type of treatment rather than the two previous ones mentioned. They are: (1) there is an almost instantaneous loss of consciousness, (2) it brings about a remission of symptoms in many cases, (3) administration is very simple and easy and (4) the cost is low.

At the present time electroshock therapy is a very common form of treatment but there is little definite evidence of an anatomical, physiological, or psychological nature as to just how it functions and brings about a therapeutic effect. Various studies have been conducted in an effort to throw light on the fundamental effect of the

electroconvulsive shock, hereafter refered to as ECS, but so far definite conclusions are impossible. Different psychological functions have been studied but so far only one study (20) has been done on the effect of ECS on a visual discrimination habit. In an effort therefore to obtain additional evidence of the effect of ECS on a visual discrimination habit the present investigation was initiated. Specifically, the problem deals with the effect of ECS on the retention of a simple visual pattern discrimination habit in the albino rat.

Historical Survey

Since Cerletti and Bini did their first work in 1937, most experimentation concerned with the effect of ECS on behavior manifestations in animals has taken place in the last decade. Although experiments and investigations are becoming more and more prevelent in the literature, as yet their number is relatively small. A survey of the studies dealing with the effect of ECS on animals is given below. These studies will be discussed under two main headings: Physiological and Psychological.

Physiological

Biochemical

In an investigation on rats conducted by Wortis et al (69), it was found that oxygen uptake was inhibited by ECS, and after repeated shocks the inhibition became greater and more marked. Swinyard (62), obtained data "showing the distribution of water, sodium, potassium and chloride in the plasma and brain of rats subjected to acute extracellular electrolyte depletion and subsequent replacement, and the relation of these alterations to concomitant changes in electroshock seizure threshold. The electroshock seizure threshold is more closely correlated with extracellular sodium and chloride concentration than with other factors examined" (p.168). From experimental findings Woodbury and Davenport (68) concluded that "normal rats treated with desoxycorticosterone acetate (DCA) or injected with isotonic NaCl or $CaCl_2$ solution have an elevated electroshock seizure threshold. Rats injected with KCl or $MgCl_2$ solution or phosphate buffer show lowered thresholds for electroshock

convulsions .... Any change of more than 3 mEq/l plasma Na is accompanied by a change in electroshock seizure threshold in the same direction."

Working with monkeys Stein and Pollock (56) found that when the animals were artificially ventilated with varying amounts of carbon dioxide-oxygen for different periods of time, threshold and superthreshold voltages did not produce seizures when the concentration of carbon dioxide was over 20% and ventilation took place for three minutes.

Kessler and Gellhorn (22) found that electrically produced convulsions tended to create a hyperglycemia in the normal, a hypoglycemia in the adrenalectomized, and produced no change in blood sugar in the adrenalectomized-vagotomized rat. They interpreted these results to mean that "convulsions excite both the sympathetico-adrenal and vago-insulin systems", with the former effect greater than the later. In a study conducted by Davenport (8), he found that the threshold for the electroshock seizure of the adrenalectomized rat was directly correlated with the plasma sodium level. Swinyard and Toman (63) conducted a study with rats that had been exposed to extreme high and low environmental temperatures. They found that seizure threshold was increased, the seizure duration was reduced, and post-seizure recovery was shortened as body temperature increased. The converse was found to take place with a decrease in body temperature.

Cerebral Effects

Wikler and Frank (65) working with decorticated cats noted

rhythmic movements of the limbs, jaws and facial musculature and a general semiflexion posture resulting from ECS. Apneatic states and transitory hyperpnea were also noted during the seizure. Nociceptive pressure stimulation following electrical seizure elicited sham rages which consisted chiefly of facio-vocal responses. No gross or microscopic changes ascribed to the electric current used to evoke the convulsions were found in the brains. They also found that decorticated cat preparations when stimulated by ECS yielded electroencephalographic patterns of relatively high voltage in bursts of 2 to 21 per second separated by short intervals. These frequently terminated in a 15 to 18 per second steady discharge before electrical activity ceased.

Rubinstein and Kurland (38) conducted electroencephalographic studies in a normal tense cat and recorded observations of 8 to 12 waves per second of medium voltage rhythm. After repeated minimal ECS it was noted that there was a decrease in the frequency of the discharges and that the voltage of the discharges decreased to zero as death approached.

General Activity and Paralysis

Page (28) states that after "grand mal" convulsions which were produced by ECS extreme passivity, inactiveness and submissiveness were manifested along with some waxy flexibility. These manifestations tended to "normalize" after two or three weeks. Winder (66) found that for a limited time following ECS voluntary activity of a group of rats was significantly lowered. In the postshock period there was a tendency toward a return to

normal activity, but after a lapse of 30 days the activity level did not reach the preshock level. In another study Winder and Stone (67) noted that during a postshock period of 30 days the mean level of activity was significantly lower than that of the preshock period. Whether this difference was due to a natural aging factor, or to the after effect of ECS could not be ascertained. Stone (58) found that rats given ECS greatly reduced their voluntary activity in a revolving drum for a short period of time. Within 24 hours after the ECS was introduced major changes appeared and it took approximately 48 hours after the last convulsive shock administration for these to disappear. The majority of animals closely approximated their preshock levels of daily activity within a two week period following the last convulsion. Rosvold and Walker (37) used a total of 21 male rats in which 12 animals served as the experimental group and were administered 9 shocks, one per day. They were then left in a cold attic compartment and given material with which to build a nest. The control group, of course, was treated in a like manner except for the shocks. It was found that "in the early post shock period the convulsed animals made no attempt at nest building whereas their controls built excellent nests. There was a gradual recovery so that by the tenth day postshock, the convulsed animals built nests equal to those of the control rats" (p.272).

In an investigation by Russell et al (42) it was found that with systematic variation of intensity and duration of ECS, a number of compression fractures and anterior dislocations were developed at the ninth and tenth thoracic vertebrae. Out of 100 animals subjected to ECS it was noted that 42% suffered

anatomical anomalies that were in direct proportion to the intensity and duration of the electroshock impulses. In a later study by Russell et al (43) it was observed that ECS caused structural damage accompanied by paralysis. It is believed by these investigators that reduction of the hyperflexion which characteristically follows the ECS will help reduce the frequency of occurrence of paralysis. Braun et al (6) also found occassional incidence of paralysis.

Convulsions

Page (28) found that alcohol and adrenalin injections had no effect on the convulsion threshold. In a later study he (29) found that air blasts or adrenalin injections did not affect the amount of electric shock needed to induce a convulsion in rats. Small amounts of alcohol did not seem to have any effect on raising the convulsion thresholds of the rats but large amounts (1.0cc) did. With repeated convulsions pronounced tremors, which the investigator considered to be psychogenic in orgin, were developed by some cats, and personality alterations such as submissive, passive, and inactive changes were recorded.

Stainbrook (50), working with the rat, showed that a response, previously attributed to high-frequency sound, could be produced by direct electrical stimulation of the brain. He further stated that incomplete or subconvulsive electrical and noise-fright induced reactions are marked by immediate righting reflex and the absence of the gross startle pattern. Stainbrook and Lowenback (55) observed that electrically induced convulsions produced a greater retardation of spontan-

eously initiated movement and a longer lasting disorientation as compared with noise-fright attacks. Stainbrook and Jong (54) observed catatonic phenomena following ECS reactions. These phenomena appeared not only after subconvulsive reactions but also transitorily after generalized seizures. Occurance of hyperkinesia in different forms was noted in rats subjected to audiogenic and electroshock reactions.

Golub and Morgan (14) observed the following five generalized types of reaction to electrically induced behavior: tonic-clonic, tonic, clonic, and racing seizures along with a "missed fits" category. It was found that racing seizures were observed at relatively weak intensities of electrical stimulation. Racing seizures also appeared prominently in sound-induced attacks and the reason given is that ear and auditory pathways in their resistance to over-loading, prevent neural excitement from building up to the level that is possible in electrogenic or pathologically induced seizure states.

In another study, Stainbrook (52) found that the motor aspect of the abnormal behavior pattern may occur in the absence of any psychological state of fear, since the electrical stimulus lasts .2 second and since the convulsive phase of the ES-NF-4 pattern is immediately precipitated in some cases. The great similarity of motor activity between the ES-NF and NF patterns signify that the NF response is also a reaction to an abnormal but not maximal neurophysiological stimulation. In the generalized ECS the catatonic symptoms manifested after either ES-NF-4 reactions have a significantly shorter duration. The author believes that "the longer-lasting catatonia of the noise-induced behavior is not entirely attributable to any convulsive

exhaustion of the animal, since the catatonic symptoms following a generalized convulsion with maximal electro-physiologic discharge of the nervous system are of significantly shorter duration" (p.263). Characteristics of the NF reaction are not only behavioral, which can probably be best described as reflecting a generalized inhibitory state of the animal, but also are of an aspect of neuromuscular dysfunction attributable to the motor expression of the reaction. Comparing the NF and ES-NF reactions to stimuli, a general more excitatory response was found in the later.

Siegel and Lacey (49) indicate that noise induced responses as compared with the electrically induced response, are one and the same. The investigators elicited both 'audiogenic' and electrically induced seizures and found them to be identical. They believed that "the implication of a common physiological mechanism is an interesting one. Certainly there is no justification for the assumption that convulsive seizures in the rat are uniquely elicited by air vibrations".

Hanzlik et al (18) found that when an electric current was passed through the brains of white rats and rabbits a clonic (epileptiform) convulsion was produced. Electrical thresholds of normal animals were raised by use of such vasoconstrictors as ergotamine, ergonovine, and fluid extract of ergot. Effective reduction of thresholds in unmedicated animals was brought about by such vasodilators as aminophylline, sodium nitrite and papaverine. According to Patton et al (30) the threshold value was lowered when auditory stimulation was given before the administration of the ECS in the experimental group.

<u>General Physiological</u>

In experimenting with anesthetized rats Porter and Stone (32) found that these animals were superior in time and errors in maze performance when compared to rats that had not been anesthetized. It was noted however, that both groups were inferior to their own preshock time performances. Siegel et al (48) concluded that anesthesia acts as some sort of protector and minimizes the disturbing effects of ECS. They believe that the disturbing effect of the shock was due to the convulsion rather than the passage of the current as such. Stone and Walker (61) indicated in preliminary results that ECS administered under ether anesthesia acts as a protection against the deleterious effects of a series of shocks, but they do not say how it functions.

Page (28) found th t his animals lost weight and concluded that in 2 or 3 weeks of convulsive free periods there was a tendency for the experimental animals to "normalize". Jensen and Stainbrook (15) found that rats gained weight concomitantly with increased food intake when a series of ECS was administered. They attribute this to water and/or lowered energy expenditure. A hyperphagia and an increase in weight accompanied the series of ECS. Townsend et al (64) noted mean weight changes in the convulsed animals. After the 15th daily shock an asymptotic level was reached followed by a general increase which was accelerated rapidly after the last shock treatment. Weight loss in rats was noted by Braun et al (6) during convulsive series. However after termination of the convulsions the weight loss was overcome.

Russell et al (41) conducted an investigation concerned

with the flow of ECS impulses and its relationship to the tissues' effective impedance. They found the following characteristics: "A very substantial relationship, in the direction of decreasing impedance with increasing impulse, exists between the magnitude of the impedance and the intensity of the impulse; a definite but small curvilinear relationship exists between the magnitude of the impedance and the number of stimulations, impedance decreasing initially and then increasing as the number of stimulations increase; and effective tissue impedance under operating conditions of electroshock stimulation consists almost entirely of pure resistance" (p.321).

Nine groups of rats were trained by Porter and Griffin (31) on the Warder-U water maze. Three different diets were used with varying concentrations of glutamic acid. After a series of ECS for 10 days the animals were again placed in the learning situation and it was found that no reliable differences in the performances of the different groups could be attributed to the differences in diet.

Genetic and Maternal Factors

Stone et al (60) in testing six different strains of mice found that none could stand the 10 milliamperes for .2 second as well as albino rats. The EXTREME DILUTE strain had a mortality rate of 11.1% as compared to the Albino strain whose death rate was 83.3%. In a study conducted by Bendig and Braun (2) 34 specially bred rats were trained to a criterion on a Lashley III water maze. The animals were classified according to fur color, sex, and litter. After a series of 25 ECS the

animals were given retention trials. Significant differences were found to exist between litters on trials for original learning and for time and trials during retention. No significant differences were manifested between fur color, strains and sexes.

Bacon and Rosvold (1) found that when a single ECS was administered to 5 pregnant rats 12 hours after mating there was no observable effect on the course of the pregnancy. However when 5 rats were given a series of ECS for 6 days beginning 12 hours after copulation, 2 of the animals manifested some degranulation pituitary acidophils, slight reduction in size of basophils, small or degenerating corpora lutea and degenerating retarded embryos in the uteri on the 11th day. Animals which received ECS for 11 days showed similar pituitary and ovarian changes and also complete destruction of the fetuses with necrosis and sloughing of the uterine lumen. In a study conducted by Rosvold (34) it was found that maternal behavior was most severely disturbed when ECS was administered from the 13th day of pregnancy to the day of parturition. He also found that the effect of the ECS is the cause for the failure of the young litter not to gain weight. According to the experimenter certain evidence suggested that the impairment was of subcortical functions. However he did not indicate the nature of the evidence. Jensen and Stainbrook (15) found, as indicated by vaginal smears, that a course of ECS created a pseudo-pregnancy in rats. The results of a later study by Rosvold (19) indicated that if shock were given rats during the latter half of pregnancy it would not cause the animals to abort, but would prolong gestation and labor. Electroshocks

given a mother rat during the last 12 to 15 days of lactation did not obliterate maternal behavior but did disrupt it considerably. It was also noted that shocks during the lactation period had a tendency to retard growth in the young. When the maternal care of the young was well established, a series of ECS given the mother rats after the 7th day post-partum, yielded a minimum effect on maternal behavior.

In an additional study Rosvold (36) found that a series of ECS given 15 hours after insemination caused the rat to terminate its state of pregnancy. If however, the series of shocks were given 36 hours after insemination 40% maintained their pregnancy, and if given 84 hours after insemination, 60% remained pregnant. Animals which had littered previously were moderately disturbed in their maternal behavior when ECS was administered during pregnancy. The severity of disturbances was dependent upon the period of the reproductive cycle in which the ECS was applied. The investigator believed that many of the dysfunctions arose directly or indirectly from endocrine disorders brought on by the ECS, but he did not cite specific evidence.

Stone and Walker (61) have found that etherization exerts a protective influence on maternal behavior when ECS was administered to pregnant rats from the 12th day of gestation to the first day after parturition.

The studies cited above indicate that ECS affects certain aspects of the rat's physiological processes and activity. As yet there are no systematic analyses of these effects as they pertain to animal physiology. Most of the studies surveyed are exploratory in nature and the theoretical aspects have not been

supported by conclusive evidence. The biochemical structure of the animal seems to be modified by ECS (8,22,56,62,63,68,69) but before complete understanding of the way in which it produces the effect is possible more investigation will be needed. There is, however, some evidence which hints at the physiological effects of ECS. This evidence (34) suggests that ECS has an effect on the subcortical functions. Other evidence (65) indicates no alteration in brain tissue due to ECS. There is a relatively large amount of evidence (1,15,34,35,36,61) to support the contention that ECS can cause disruptive changes in gestation and maternal behavior. According to one theory (36) this is due to endocrine dysfunction which is a resultant effect of ECS. Weight changes were noted by several investigators (6,15,28,64), but no complete agreement as to just how ECS brings about the change is offered at present. No conclusive evidence to support a particular theory has as yet been presented, however with the advent of systematic treatment of the fields opened by exploratory studies a better understanding of the effects of ECS on the physiological aspects of infrahuman species may be forthcoming.

Psychological

Learning

After a criterion was established for double alternation lever-pressing, McGinnies and Schlosberg (26) found that the electric current passed through the head caused a breakdown of the learned habit in all rats. They suggest that for a short period following ECS the rat cannot profit from retraining.

The hypotheses offered to explain the behavior are that the convulsions decrease activity levels, thereby impairing performance and that cerebral anoxia induced by the convulsion causes a temporary loss of retention.

Horowitz and Stone (19) tested the hypothesis "that a previously learned habit, disorganized by ECS, would give less interference with the learning of a new habit." They found a measurable disorganizing effect on the original habit in the experimental group, however the control group learned the habit more readily; therefore they discarded the original hypothesis.

In a later experiment conducted by Horowitz and Stone (20) two groups of albino rats were used in the Stone(57) serial light discrimination apparatus. There were 10 animals in the control group and 13 in the experimental group. Both groups had to satisfy a criterion of 4 out of 5 errorless trials, the correct alley being the lighted one. The experimental group received a series of 15 ECS after each daily trial and then 10 days of pseudo shock. During the same period the control group received 25 days of pseudo shock. For approximately the next 25 days the experimental and control groups were given training on an interfering habit in which the dark windows were now positive and indicated the correct pathway. A statistically significant difference was found between the control and experimental groups in their response to the light-dark discrimination. Within 10 days after the discontinuance of the shocks the experimental group's performance improved and almost reached that of the control group. The investigators believed that if given enough time a complete recovery from the deleterious effects

of 15 ECS as measured by the light discrimination method would occur in the albino rat. Braun and Patton (5) found that a series of 12 ECS disorganized a recently acquired habit and reinstated a previously learned habit only when the recent habit was relatively more difficult. However a simple task was not disrupted to the extent that previously learned habits superseded it.

In an investigation conducted by Duncan (10) it was found that ECS causes an amnesia or disorganization of recent habits, thus allowing older incompatable habits to gain dominance. In another study by the same investigator (11) rats were taught to avoid a charged grid. After 18 days of learning the experimental group was given a series of controlled ECS. The results indicate that perhaps newly learned material goes through a period of consolidation or perseveration, and if during this time ECS is given the effect of learning may be obliterated if shocked soon enough after learning the material. After about an hour the newly acquired material becomes far more resistive to ECS disruption.

Stainbrook (53) found that no significant differences were established in the rate of learning between a group of animals found to be susceptible to noise-induced behavior disturbances and rats selected for the ECS group which were not readily susceptible to noise-induced behavior disorders. It was also noted that the last-learned responses were affected by ECS more so than the first-learned choice point discriminations.

Eriksen et al (12) in their study of rats trained on a Stone Multiple T-maze found that the time score difference

favoring the control groups merely reflected differences in rate of error elimination. They failed to note any gross behavioral differences between the experimental and control groups, either before or during maze trials, and it was only upon statistical analysis that performance differences became evident. Porter et al (33) working with young rats in a learning situation found that ECS effects a small permanent decrement in ability to learn a relatively difficult maze (Stone's Multiple T-maze). The investigators believed this decrement was caused by brain injury, from which there was rapid but partial recovery, but they did not cite any substantiating evidence.

Stone (59) gave infant rats a series of ECS which lead to deficits in maze learning which could be demonstrated more than 75 days after the last convulsion. He believes that this reflects a permanent reduction in maze learning ability. Muhlhan and Stone (27) using a Dashiel-type water maze found that 16 to 20 days after cessation of shock the convulsed group showed no handicap in a problem requiring acquisition of new routes from start to exit as compared with the control group.

Russell (39) found that in a relatively simple straightway or single-choice-point maze, learning and retention, either immediate or delayed, are not affected by a series of controlled ECS. A similar conclusion was reached by Siegel (46) and by Stainbrook and Lowenback (55). On the other hand, a five-choice-point maze used under the same conditions showed significant decrements in both learning and retention, in immediate and the delayed situation. The experimenter thus believes that the effects of ECS on learning and retention are in part dependent

on the difficulty of the task involved.

Retention

Stainbrook and Lowenback (55) trained rats in a simple right-wrong position discrimination water maze. They found that as far as error scores were concerned, the maze performance of rats did not appear to be affected by a long series of convulsions induced either by electric shock or by noise-fright stimulation. "Experimental neurosis" was usually displayed by rats starting in after the 2nd to 5th ECS. It was found that immediate post-convulsive maze performance for both groups (NF and ES) in regard to errors was the same.

Siegel (46) trained rats in a simple running situation after a series of ECS. There was no difference in habit retention when the control and experimental animals were returned to the learning situation. Stainbrook (51) found that on a two decision-point, right-left T-maze the relearning time and error scores were significantly greater for the experimental group than for the control group. He believed that relearning errors of the ECS animals may have been conditioned by the "emotional" behavior induced by the ECS.

Using a Lashley III maze Duncan (9) noted that the experimental group (ECS) was significantly inferior in trials, errors, and time spent during relearning when compared to the other groups. The results indicate that the major loss seems to be in retention, and that ECS causes central nervous system impairment that manifests itself in a loss of retention or relearning ability, or both.

McGinnies (25) trained animals on a 14 unit elevated maze and noted that during the ECS series no increase in error scores was shown, but that the average running time was increased. "An explanation is offered in terms of individual differences in levels of adaptability to physiological stress caused by the convulsions, rather than in terms of direct neural effect of the current" (p.36). Stainbrook (53) used a running food-reward T-maze and found that severe maze performance dysfunction was observed in the ECS animals although there was significant evidence of the retention of the general characteristics of the maze.

Using a Lashley III maze modified for swimming Braun et al (6) found that a decrement in retention which was at least as great as that demonstrated immediately after the convulsion appeared 60 days after the convulsive series. Townsend et al (64) showed that a decrement occured in the maze habit immediately after a series of controlled ECS, but that the magnitude of decrement of retention was not related to the intensity of the electroshock impulses used to induce the convulsions. In an investigation conducted by Braun et al (7) the results indicate that the experimental group which received a series of ECS was significantly inferior to the control group in terms of relearning trials, errors and time scores. These investigators believe that a series of controlled ECS creates a permanent impairment in the retention of a habit of the complex nature as found in the Lashley III maze.

In an experiment performed by Siegel and Siegel (47) the anticipatory gradient was almost completely abolished by the

administration of ECS, however it did return with considerable uniformity when a post-convulsive series of daily trials was given.

Conditioning

Page (28) noted that some evidence of conditioning was elicited by all animals, but no true "conditioned convulsions" were ever obtained. Kessler and Gellhorn (23) conditioned rats to respond to a bell and then inhibited the response by lack of reinforcement. It was found that in a control experiment the response thus inhibited did not recover spontaneously, but after one or more metrazol or ECS seizures a temporary restoration of the inhibited response was manifested.

Gellhorn (13) found that when he established conditioned reactions in rats and then inhibited them, there was a simultaneous recovery when a hypoglycemic coma or when ECS was administered. He believed that ECS and insulin coma might act specifically on inhibited conditioned reactions. Patton et al (30) did not find any conditioned response seizures elicited by the presentation of the auditory stimulation prior to shock in any of his animals.

Masserman and Jacques (24) performed an experiment in which six cats were experimentally made neurotic and then subjected to ECS. They found that "all the animals showed a marked disintegration of inhibitions, phobias, compulsions and other neurotic patterns, with emergence of simpler, more normally readaptive behavior which could be further improved by guidance, retraining, and other corrective procedures" (p.98).

The neurotic animals showed impaired capacity for complex adaptations.

In a study conducted by Hunt and Brady (21) 20 male albino rats were conditioned emotionally in a Skinner Box. The conditioned stimulus was a clicking sound reinforced by a mildly painful electric shock delivered through a floor grid. On the basis of strength of lever and emotional response and the ease and rapidity of establishment of the emotional response the subjects were divided equally into control and experimental groups. The experimental group was then given 21 ECS, administered three per day for seven days, and the control animals received the same number of pseudo shocks during this time. The results indicated that the ECS virtually "eliminated or diminished" the conditioned emotional response that was established prior to the convulsive series. A follow up investigation by the same investigators (4) confirmed the results found previously.

In a recent experiment Brady (3) investigated the possibility that with the passage of time alone, some change occurs in the conditioned emotional response which may influence the effect which ECS can have upon such a response. The results of this study "suggest quite strongly that the conditioned emotional response increases in strength with elapsed time and that this increase in strength (or, perhaps, change in quality) may be sufficient to obscure the effects which ECS has upon the response" (p.13).

Emotion, Reasoning and Cognition

In a study by Siegel (46) no difference in habit retention

was recorded in animals that had been shocked and placed back in the learning situation. However a temporary discrepancy in relearning ability was attributed to emotional disturbance rather than to cognitive loss.

Sharp et al (45) found evidence indicating alteration and impairment in the performance of rats in the Maier "reasoning" test after ECS. An inverse relationship appears between the amount of disturbance and length of the period of recovery after individual shocks.

Hayes (17) attributed decrement in maze behavior to a cognitive loss rather than to fear or to physical weakness. The general findings of this experiment were unfavorable to a cortical damage hypothesis, but no explanation was made to account for the cognitive loss.

In summarizing briefly the results of studies reviewed under psychological experiments it can be seen that most of the studies surveyed have merely opened new pathways of research and do not give definitive answers. At present, it is difficult to cite specific principles that clearly indicate just how ECS functions, since the systematic experimentation required for such statements is lacking. There are however certain trends which are evident.

In the learning area there is evidence (10,11,12,19,20,26, 33,39,59) to support the contention that ECS causes a decrement in learning ability. On the other hand the results of two studies (27,39) indicate contradictory findings. Investigations dealing with retention show two general trends. Decrements in retention were found by (6,7,9,51,64), however

(25,46,55) did not find any increase in error scores when their animals were subjected to ECS. The effect of ECS on a conditioned response, which was later inhibited, was found temporarily to restore the inhibited response (23). In two studies (4,21) conditioned emotional responses were diminished and virtually eliminated by ECS. Decrements in maze behavior are ascribed to cognitive loss (17) due to ECS, rather than to fear or to physical weakness. "Reasoning" was found to be altered and impaired as a result of ECS (45).

It is thus seen that there is a relatively large number of studies which support the claim that ECS affects psychological functioning. But the precise manner in which it does so is not as yet understood.

A summary of hypotheses that have been put forth concerning the fundamental effects of ECS is based, in the main, on speculation. Such hypotheses may be classified under two general catagories, physiological and psychological.

Under physiological theories brain injury (33) and central nervous system impairment (9) have been mentioned, but contradictory evidence is cited (65) in which no gross or microscopic changes in brain tissues were found following ECS. According to another investigation (26), ECS decreases activity levels and produces cerebral anoxia which causes a temporary loss of retention. One experimenter (34) suggests that ECS causes an impairment of subcortical functions, but later (36) adds that many of the dysfunctions that arise as a result of ECS may be due directly or indirectly to endocrine disorders.

Under psychological hypothesizing, one study (17) attributes a cognitive loss due to ECS. Other evidence (46)

is not in agreement with this viewpoint and it is believed that ECS creates an emotional disturbance which in turn produces a temporary discrepancy of learning ability. This hypothesis is suggested by another worker (51) who attributes relearning errors of ECS animals to the emotional behavior induced by the ECS. An additional hypothesis (10) offers the explanation that ECS causes an amnesia or disorganization of recent habits.

The Experimental Investigation

I Problem

In this investigation the problem was to determine the effect of ECS on the retention of a simple visual pattern discrimination habit in the albino rat. The effects of ECS were measured by the degree to which the animals that received the convulsive shocks could retain a visual discrimination habit in comparison with a control group of animals that did not receive any ECS. The hypothesis involved in this problem is that the effect of ECS on retention of a simple visual pattern discrimination habit in the albino rat is null.

The implications of this investigation invade several areas of psychology and psychiatry. One of the most basic and important implications of this study is the relation it bears to electroshock therapy in humans. ECS as applied to humans is usually not designed to determine the basic effect, psychologically, physiologically or neurologically, of the electric current on the patient. Salzman (44) in an article evaluating shock therapy has stressed the need for research and more extensive studies before conclusive statements can be made concerning the effects of ECS. There is, therefore, little systematic data bearing on this topic. However, it is often impossible for many reasons to do exact research on hospital patients or normal subjects and so animals have been used. The relationships between human and animal behavior are such that valuable data can at times be obtained which have a bearing on human behavior. It is hoped that studies such as this, and others, will help clarify some of the fundamental problems concerning the basic

effect of ECS on animal and perhaps also on human behavior.

More specifically this study has a bearing on the effect of ECS on the visual behavior of the rat. In case a series of ECS does affect the retention of a simple visual discrimination habit in the albino rat, the question could be raised as to whether the basic effect results from organic brain damage of the visual projection pathways, from endocrine disturbances, or from some emotional or cognitive impairment. It may be that a simple visual pattern discrimination is retained to a greater degree after a series of ECS than a discrimination of a more difficult nature.

Other questions which should be answered eventually are: How does the number of convulsions used in a series of ECS, or the length of time that the current is passed through the animal's head, affect a visual discrimination habit? Does a series of ECS affect visual retention permanently, and if not, how long does the effect last? These questions and others can not be conclusively answered with our present knowledge.

II Apparatus and Subjects

A. Apparatus

The discrimination apparatus used in this investigation was a modified version of the Munn visual discrimination box. Figure I shows the floor plan of the apparatus. The overall length of the apparatus was 34½", and the width varied from 4" at its narrowest point to 10½" at its widest. It consisted of three compartments which are as follows: (1) a starting compartment (SC) 4" by 8"; (2) a discrimination compartment

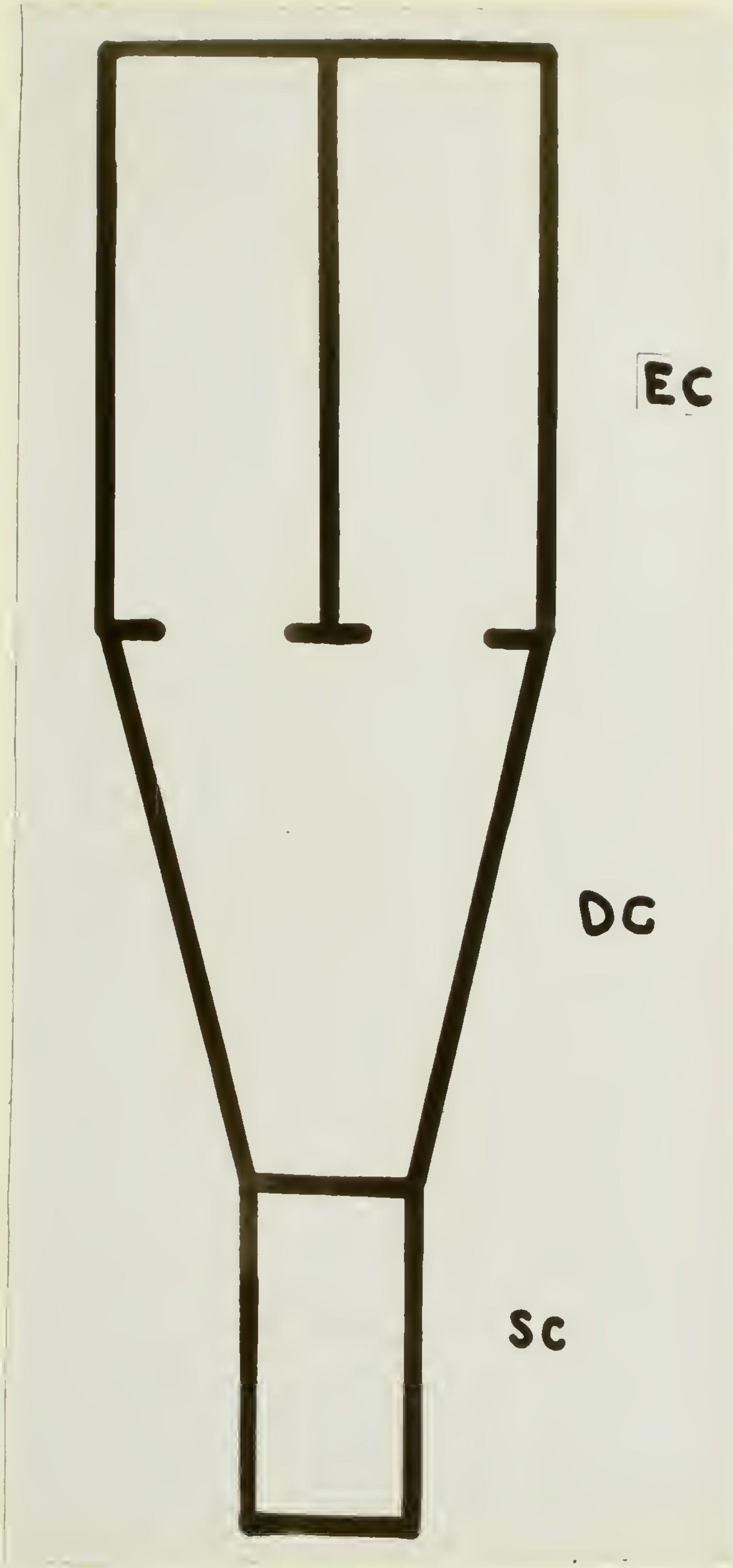

Figure I

Floor plan of modified Munn
visual discrimination apparatus

Stimuli used for visual discrimination

Positive Negative

Figure 2

(DC) 4" by 12½" by 10"; and an (3) exit compartment (EC) 10½" by 13 3/4" respectively. The cards which bore the stimuli to be discriminated were placed in the exit doors as shown in Figure 2. These doors were hinged at the top and hung in the entryway to the exit compartment.

For the first four days of the discrimination learning stage two exit compartments were used. Exit compartment #1 had the positive door on the right and the negative door on the left, whereas exit compartment #2 had just the opposite arrangement. Beginning with the 5th day of the discrimination learning, and from then on, a single exit compartment was used. The single exit compartment proved to be less cumbersome and time consuming than the two exit compartment technique. This single exit compartment had exactly the same dimensions as the one previously used except that the stimulus strip on each door could be rotated. By means of this pivoting mechanism, dull black cardboard strips measuring 5/8" by 2½" were attached to blank white cardboard cards that measured 3 3/4" square. They were attached in such a manner that the strips, which were placed in the card's geometric center, could be pivoted on each door to either a horizontal or vertical position by the experimenter. The black strip in a vertical position indicated the positive stimulus, and when rotated to a horizontal position it indicated the negative stimulus. Whenever the stimuli or the white cards on the doors became soiled, clean ones were substituted. The pivoting mechanism attached to the rear of the door consisted of a small brass knob, a shaft, a tension spring, and a cross bar that supported the entire pivoting

mechanism.

A locking mechanism was mounted at the rear and to the outer side of each door frame so that the negative door could always be locked. In the preliminary training stage a set of sliding panels was used. This permitted the closing of one entryway at a time to the exit compartment in a prearranged randomized order. After the preliminary training stage the set of panels was removed and not used on the apparatus.

Both the starting compartment and the discrimination compartment were covered with clear window glass in order to keep the rat confined and to permit observation. The inside of the entire apparatus was painted a flat gray and the outside a dull black. Two 60 watt bulbs in white enameled reflectors placed 18" above the apparatus and along its median line were the sources of illumination. One of the lights was placed above the center of the starting compartment and the other one was over the center of the discrimination compartment. The two lights illuminated the stimulus cards evenly and did not cast any shadows on them. The sources of illumination were kept in a constant position.

A grid made of 1/16" copper strips, 1/8" apart served as the floor in the starting and discrimination compartments. The copper strips were wired so that alternate strips were connected to the positive pole of the inductorium, the others, to the negative pole. The shock-producing apparatus which charged the grid consisted of an inductorium and a 1.5 volt dry cell battery, wired so that by manually throwing the appropriate switch either the grid in the starting or discrimination compartment could be electrified. The secondary coil

of the inductorium was set at a constant position throughout the experiment. The intensity of the shock was not of such a magnitude that when the grid was electrified a normal rat would react by raising its fore paws and by making minor escape movements. The inductorium and battery were placed in a sound proof metal box with leads to the shocking switch and to the grids. The sound proof metal box rested on a 3/4" sheet of celotex. This helped prevent the vibrations created by the inductorium from being transmitted to the discrimination apparatus. A Standard Electric Time Clock calibrated in seconds was used for timing the animals' discrimination time.

The ECS apparatus was built at the University of Massachusetts and was patterned after the "Pittsburgh Electro-Shock Apparatus" as described by Russell et al (40). It operated on a 110 volt alternating current and could be adjusted for a given amperage and for a constant period of time. The characteristics of the current used to produce the convulsions were as follows: 60 cycle, alternating; sine wave form; maximum possible voltage, 150; minimum voltage, zero; milliamperes, 20; duration, one second. Battery clips, with round, silver plated, cup-shaped electrodes (9 mm in dia.) attached to them, were used to fasten the electrodes to the animal's ears in order to apply the current to the rat. Each of the two battery clips containing the electrodes was soldered to the end of a four foot insulated copper lead which in turn connected to a terminal of the ECS apparatus. Prior to being clipped on to the rat's ears the silver plated cups of the electrodes were filled each time with Burdick electrode paste.

The paste was used to insure a uniform electrical contact.

In order to cushion and absorb the convulsions of the animals, they were placed feet down on a small soft pillow (14"x12"x2½") which rested upon a regular size pillow (18½"x 15½"x3½"). The small pillow was covered with a sheet of clear cloth-like plastic in order to prevent the rat from soiling the pillows. Thus in the initial reaction to the convulsive current, the rat instead of being able to react against a hard surface and arch its back sharply, sank its feet into the pillow and in so doing dissipated most of the convulsive violence harmlessly. This technique reduced the number of spinal fractures materially.

B. <u>Subjects</u>

Twenty seven male albino rats from the Wistar strain of the Hatch Laboratory of the University of Massachusetts were used as subjects in this experiment. The animals' birth dates ranged from July 8 to July 20, 1950, and they were approximately 16 weeks old at the beginning of the investigation. During the experiment the animals were housed in single cages with individual water bottles which permitted water consumption ad libitum. The animals' diet consisted of Purina Fox Chow (With Meat Meal), supplimented at intervals with small amounts of lettuce.

III Procedure

A. Experimental Design

The procedure of this investigation was divided into four stages. The first was the preliminary training stage, in which the animals became accustomed to the experimental apparatus. The second was the discrimination training stage in which a record was kept of each animal's trials, errors, and time per trial required to satisfy the criterion of learning. The third was the electroconvulsive stage in which the experimental animals were subjected to ECS, while the controls rested, and the fourth and final was the discrimination relearning stage, in which records were kept of the number of errors, trials and the length of time per trial it took each animal to reach the relearning criterion. All animals were run at approximately the same time each day and were under a 20 to 24 hour hunger drive. Each animal was given approximately 15 grams of wet mash per day for the first 13 days of the preliminary training, at this time the ration was increased to approximately 30 grams of wet mash per day and remained the same until the completion of the experiment. During the preliminary training the animals were not run on Sundays. However, once the discrimination learning stage had started the rats were run every day. Table 1 summarizes the experimental design of the investigation.

Table 1

Experimental Design of the Investigation

Group	Stage 1	Stage 2	Stage 3	Stage 4
Experimental	Preliminary Training 17 Days	Learning	10 Days ECS	Relearning
Control	Preliminary Training 17 Days	Learning	10 Days Rest	Relearning

B. Preliminary Training

All animals were started on the preliminary training on the same day. The first stage of this training consisted of enabling the rats to become familiar with the experimental apparatus. This was accomplished by letting them explore the apparatus freely in groups of four and five for 15 minutes per day for five days. During this time both doors to the exit compartment were opened 90 degrees and had blank white cardboard cards in them. A small glass caster of food was placed in each subdivision of the exit compartment so that the animals would be equally motivated regarding the choice of subdivision of the exit compartment. Panel #1 of the starting compartment was closed which prevented the rats from walking out, and if any of the animals tried to leave the apparatus by climbing over the side of the exit compartment the experimenter prevented this by replacing any that attempted to

do so. A glass cover over the starting and discrimination compartments prevented the animals from climbing out. After the five-day familiarization period the animals were segregated for the remainder of the experiment by placing each one in a single cage. Prior to this time they had been housed four or five to a living cage.

Following this the animals were trained individually to leave the starting compartment, enter the discrimination compartment, and go through the open doorway to the exit compartment. In order to pass from the discrimination compartment to the exit compartment the two doorways permitting entry to the exit compartment were closed, one at a time, by a set of sliding panels in a prearranged randomized order. As an example, the first day's random order was as follows: left,right, right, left, right, right, left, right, left, left. Eight different randomized orders, each having 10 trials, made up of 5 right, and 5 left responses were followed. On each ninth day the cycle of random orders for each rat was started over again. In closing the sliding panels not more than three consecutive closings were made on either left or right side in the ten trials per day for each rat.

A typical trial was conducted in the following manner. First panel #1 was raised by the experimenter, the animal was placed in the starting compartment, and the panel was lowered again. Then panel #2 was lifted which permitted entry into the discrimination compartment. As soon as the rat entered this compartment panel #2 was lowered again. After a rat entered one of the subdivisions of the exit compartment he was

allowed to eat a few mouthfulls which took about five seconds and then he was picked up and given another trial in the same way as indicated above. Each animal was given ten trials per day and after an animal completed his tenth trial for the day, he was placed in his home cage and given his daily portion of wet mash. This procedure was followed for the next four days. All of the rats were well motivated and readily learned to traverse the discrimination apparatus with out any delay (without being shocked) in the starting or in the discrimination compartments.

The next three days were devoted to training the rats to go through the closed doors. This was accomplished as follows: On the 10th day of the preliminary training stage the doors which had been open 90 degrees were lowered so that the bottom of the door was $3\frac{1}{4}$" from the floor of the exit compartment. The doors were held at this level by black nylon thread fastened from a small metal wire loop on the back of the door to a metal frame of the discrimination apparatus. The next day the doors were lowered until they were $2\frac{1}{4}$" from the floor of the exit compartment. The following day the doors were open 1" and the day after that the doors were completely closed. At this point the animals had to push open the proper door in order to pass through it to the exit compartment. This last procedure was continued for five days to insure that each rat had thoroughly mastered the habit of going through the apparatus to the exit compartment. The responses right and left were randomized by lowering one of the sliding panels in front of the negative door.

C. Discrimination Training

The discrimination training period began 24 hours after the fifth day of the rats going through the closed doors. The cards bearing the stimuli to be discriminated were substituted for the blank cards. Records were kept of the animals' errors, trials and time per trial required to learn the discrimination between the positive and negative stimulus cards.

A typical trial during the discrimination training was as follows: The rat was placed in the starting compartment by lifting panel #1 and then lowering it after the rat was inside the starting compartment. Next, panel #2 was lifted which permitted the rat to enter the discrimination compartment. As soon as the rat left the starting compartment the electric time clock was started and panel #2 was lowered. The rat was now in the discrimination comprtment and had the opportunity to make a positive or negative response. A positive response was defined by the animal's going through the door which contained the positive stimulus card (vertical black strip). A negative response was defined by the rat's touching the negative stimulus door (the door having the horizontal black strip) with any part of his fore body. As soon as the rat made a discrimination response the electric time clock was stopped, and the time to make the discrimination was recordéd along with the discrimination response. The rat was then allowed to have a small amount of food (a mouthful or two), after which he was picked up and replaced in the starting compartment

to begin his second trial.

The criterion of learning was established at nine or more correct responses on three consecutive days. As an animal reached criterion he was placed in either an experimental or control group in a counterbalanced order. Thus the rat that reached criterion first was placed in the experimental group. The second and third rats that satisfied the criterion were placed in the control group, and the fourth rat reaching criterion went into the experimental group. If an animal did not learn after 300 trials or 30 days, he was discarded. Seven animals were discarded.

As each animal approached the criterion the black strips were each rotated on every trial finally being placed in the proper position. This was done to determine whether the experimenter's altering the positions of the strips served in any way as a cue to guide the animal's discrimination. At no time did it provide any observable alteration in the rats' responses.

During the course of the experiment 13 animals manifested position habits at various times. A position habit was defined by the rat's choosing the right or left side of the exit compartment for 10 consecutive trials in one day. Of these 13 animals 5 were discarded due to their inability to satisfy the discrimination learning criterion. Four of the remaining 8 animals manifested position habits during the discrimination learning and 4 others exhibited position habits during the discrimination relearning.

During the discrimination learning, the position habits of three of the rats were broken up by shocking them as they approached the negative door when it appeared on the side of the position habit. The others were broken up simply by continuing to run them in the usual manner. Of the three animals that were shocked for position habits, two broke in one day after shocking, the other animal received two days of shocking and then broke the position habit. Two of the animals whose position habit was broken up by shocking were placed in the experimental group, the other one was placed in the control group.

D. Electroconvulsive Shock Procedure

Twenty four hours after each experimental animal reached the criterion he was started on the series of 10 ECS, administered one per day. The convulsive shocks consisted of 20 milliamperes applied for one second. Twenty four hours after each control rat reached the criterion he was started on a 10 day rest period without receiving the ECS. Psuedoshocks were not given the animals of the control group since it was believed that this procedure would produce a significant amount of emotional disturbance that could not b e controlled or measured. Neither the experimental nor control animals were run in the discrimination apparatus during the series of 10 ECS or the 10 Days of rest. The procedure for administrating the ECS to an animal was as follows: The animal was removed from home cage and held gently but firmly by an assistant while

the electrodes were clipped on to his ears. The rat was then lowered to the small pillow and the assistant cupped his gloved hand over its back. When the proper pressure and position was attained the ECS switch was thrown and the animal went into a typical convulsion. The electrodes were promptly removed from the ears of the animal and a record was made of his behavior during the convulsions. When the animal ceased his convulsions he was picked up and returned to his home cage. A record of the characteristics of the convulsions exhibited by each ECS animal was kept.

Braun et al (6) (p.96-97) described a typical convulsion in a rat subjected to 20 milliamperes for a duration of one second as follows:

> "With the application of the current, the rat gave a start, with the spine flexed ventrally, and fell on its side with the hind legs drawn up and the front legs brought down. After two to four seconds, the animal passed into a state of 'tonic contraction' of all of the bodily musculature, the extensors predominating. The eyes were closed, the ears laid back, the fore paws were held rigidly to the sides, while the hind limbs were in extension. ..... a brief cessation of breathing, and usually ejaculation, defecation, and urination were observed as well as an occasional appearance of reddish material from the orbit. Approximately 15 to 20 seconds following application of the current the tonic stage gave way to clonic movements, which involved principally the hind legs but which affected the whole skeletal musculature. This clonic stage lasted for an additional 20-25 seconds, following which there appeared a catatonic stage characterized by waxy flexibility and an impairment of placing and righting reflexes."

In this investigation each of the rats went through convulsions having the same general characteristics as described

by Braun et al (6) above. However as might be expected there were many minor individual differences exhibited. Some of the rats were irritable, while others were quite stuporous in the catatonic stage following the seizures. Two animals had to be discarded from the experiment due to paralysis of the hind legs which was caused by the ECS.

E. Relearning Discrimination

Twenty-four hours after each experimental or control animal had completed his ten days of ECS or rest period respectively, he was reintroduced into the discrimination apparatus for the relearning trials. Thus the animals again had to satisfy the original criterion of mastery of nine out of ten correct discrimination responses for three consecutive days. After an animal had satisfied the relearning criterion he was no longer used in the investigation. The procedure of handling some of the ECS animals in the relearning situation was slightly different than in the original learning. This was due to the fact that some of the experimental rats did not readily traverse the apparatus as they had done before. The procedure used was as follows: The animal was placed in the starting compartment and given 30 seconds to proceed into the discrimination compartment. If after 30 seconds the animal did not leave, then 30 seconds of shock at the rate of two per second were administered to the animal by the grid in the starting compartment. If then the animal did not depart from the starting compartment after 30 seconds of shock, a "no

response" was recorded for him for that trial. He was then taken out of the apparatus and kept out for approximately one minute, at the end of which he was replaced into the apparatus and given another trial. Only one rat in the experimental group of all the subjects used made two "no response" trials on the 5th day of the discrimination relearning stage.

IV Results and Discussion

A. Quantitative

A comparison of control and experimental groups was made on a basis of trials, errors, and times per trial in order to determine the degree to which both groups were equated in the original learning discrimination. Table 2 shows the mean of trials, errors and time scores (in seconds) for the experimental and for the control groups for original discrimination learning. In order to find out whether the mean differences between experimental and control groups were significant, Fisher's small sample t formula was used. The formula is as follows:

$$t = \frac{M_e - M_c}{\sqrt{\left[\frac{\Sigma x_e^2 + \Sigma x_c^2}{N_e + N_c - 2}\right]\left[\frac{N_e + N_c}{N_e N_c}\right]}}$$

These statistics were computed in order to determine whether the experimental and control groups were alike in their learning ability. The statistical results indicate that the trials, errors, and time score means between the control and experimental

groups do not differ significantly. Thus the small difference manifested between the control and experimental group can be said to occur by mere chance factors operating and not any significant difference in the learning ability between the two groups. The assumption is then made that the results as found in Table 2 would occur in random sampling from a common population. The further assumption is made that the experimental and control groups with regard to learning ability were essentially equal.

Table 3 shows the resultant differences between the means for trials, errors and time scores for both groups in satisfying the relearning criterion. The means of trials, errors and time scores between the control and experimental groups were significantly different below the one percent level of confidence. These results indicate that in terms of trials, errors and time scores the behavior of the experimental group was altered to such an extent that statistically speaking the difference manifested would appear less than one time out of a hundred.

Table 4 contains statistical data which presents the results in a different manner. The table shows the mean difference of trials, errors and time per trial between the original discrimination learning as compared with the discrimination relearning for the control and experimental groups. The results indicate that for mean differences in trials between the experimental and control groups there exists a significant difference below the five percent level of confidence,

This means that a difference existed between the experimental and control groups, and the difference was of such a magnitude that it proved to be statistically significant. Significant differences were also found for mean differences in errors and time scores for both groups below the two and one percent level of confidence, respectively. This evidence corroborates the findings in Table 3 which indicate significant differences between the two groups regarding trials, errors and time per trials.

B. Qualitative

It will be recalled that 24 hours after each experimental or control animal had received his last ECS or finished his 10 day rest period he was started on the relearning series. None of the control animals displayed any emotional disturbance on being started on the relearning series, and none of them delayed as long as 30 seconds either in the starting compartment or in the discrimination compartment. However, three of the experimental rats displayed a degree of disturbance on being introduced to the apparatus for the relearning series. This behavior was observed while the animals were being placed in the starting compartment as well as while they were in the discrimination compartment. It was undoubtly not due to the effect of the shock from the grid, since all 7 experimental animals were shocked via the grid and only 3 of them reacted in this manner. This behavior however subsided in one day for rat #23, in 4 days

for rat #27, and in 7 days for rat #16. The behavior consisted of the animals crawling to a corner of the apparatus, squealing, trembling, and defecating and, in light of Hall's (16) criteria for defining emotional behavior, is best characterized as emotional. It was noted that all of the experimental animals delayed before leaving the starting compartment or before making a discrimination once in the discrimination compartment. These animals were motivated to go through the apparatus by being shocked via the grid.

C. Discussion of Results

In discussing the results it must be remembered that all of the experimental animals were motivated by being shocked, via the grid, when placed in the relearning situation. They were shocked in the discrimination compartment on certain days and for certain trials. The shocks generally had to be administered for the first trial of each day. The number of shocks via the grid which each experimental animal received was as follows: #5 - 4 shocks; #8 - 23 shocks; #12 - 9 shocks; #15 - 3 shocks; #16 - 11 shocks; #23 - 1; and #27 - 3 shocks.

The delay of the experimental animals had not been entirely expected since the 17 days of preliminary training had been designed to over trian them in going through the apparatus. There is a possibility that the shock applied to all of the experimental animals to enhance their motivation may have caused an emotional disruption that might explain the results. the answer to this question is not positively known, but the

evidence tends to yield the conclusion that any emotional disruption caused by the shock was not of such a magnitude as to be entirely responsible for the statistical results. The evidence is that only three experimental animals (#'s 16,23,27) manifested any emotional behavior and this number represents less than half of the experimental group. Furthermore it is believed that although electric shock has been used as a motivating factor in many animal learning studies the emotional effect of one or two such shocks probably does not last more than a few minutes at a time. Thus the shock from the grid can most likely not be used to explain the break down of the discrimination habit of the experimental animals.

Records of qualitative behavior indicate that the emotional disruption from the ECS was present in only three of the seven experimental animals that received shock, and out of those 3, one rat manifested some emotional disruption for one only while the other two behaved emotionally for 4 and 7 days respectively. Thus less than half of the experimental group manifested any observable emotional disruption at all, and only two animals manifested it for more than one day. Since all the experimental animals were shocked, one would expect - if assuming that shocking the animals may have caused the emotional behavior - all 7 experimental animals to manifest emotional behavior, while actually only 3 behaved emotionally out of the experimental group. It is believed therefore, that any emotional disturbance resulting from the shocking of the animals did not play a significant role in

determining the results.

On the assumption that the ECS does cause a significant differential behavior, then how can it be explained? It is possible that the ECS might have caused a loss of the habit of traversing the apparatus. This might well account for the difference between the two groups with respect to the average discrimination time per trial. However, the significant differences between the control and experimental groups in trials and errors point to the probability that the ECS effected a partial destruction of the discrimination habit. If it had not, then it would have been expected that the rats, even though retarded in their traversing of the apparatus, would nevertheless have made few errors or none at all, in the relearning of the discrimination.

The analyses of the quantitative and the qualitative data indicates that the effects of ECS on retention of a simple visual pattern discrimination habit in the albino rat are not null; the experimenter, therefore, must reject the hypothesis of no difference. It is not fully understood just how and in what manner ECS causes a detrimental effect on the discrimination process. Several theories of the effect of ECS have already been treated in another part of this paper, however the data of this study do not make it possible to explain how or in what manner ECS has a disrupting effect on the simple visual pattern discrimination habit.

Although there are differences, in general, the results of this experiment are in agreement with those of other workers (6,7,9,51,64) in the area of retention. The findings of this

investigation are consistent with those of Horowitz and Stone (20), since they also noted a statistically significant difference between the control and experimental groups in the performance of a visual discrimination habit.

V Summary

Twenty seven male albino rats were trained to discriminate between a horizontal stimulus and a vertical stimulus on a modified version of the Munn visual discrimination apparatus. When an animal reached the criterion of learning he was put in either an experimental or control group in a counterbalanced order. Twenty-four hours after reaching the learning criterion the experimental rats were given a single ECS for each of 10 consecutive days and the control animals were given 10 days rest. Upon completion of either the ECS series or rest, the animals were again required to satisfy the same criterion of mastery. Differences between the experimental and control group in respect to trials, errors, and time per trial were statistically treated and corresponding probabilities of these differences were computed. The results tended to show that a significant difference existed between the control and experimental groups with the controls superior in trials, errors and time per trial. It is believed therefore that a 10 day series of electroconvulsive shocks has a detrimental effect on the retention of a simple visual pattern discrimination habit in the albino rat.

Table 2

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

	Original Discrimination Learning				
	Exp.	Cont.	Difference Bt. Means	t	p
N	7	10			
Mean Trials	62.86	98.00	35.14	1.178	>.05
Sigma	36.14	67.64			
Mean Errors	23.43	28.90	5.47	.678	>.50
Sigma	11.55	17.56			
Mean Time (in seconds)	156.29	226.40	70.11	1.178	>.05
Sigma	69.96	135.79			

*All statistics in Tables 2,3 and 4 were computed on results up to but not including criterion trials.

Table 3

Comparison of discrimination relearning between experimental and control groups in terms of mean trials, mean errors, and mean time.*

	Discrimination Relearning				
	Exp.	Cont.			
N	7	10	Difference Bt. Means	t	p
Mean Trials	74.28	15.00	59.28	3.682	<.01
Sigma	41.36	20.12			
Mean Errors	29.28	3.80	25.48	4.182	<.01
Sigma	17.10	4.96			
Mean Time (in seconds)	574.00	39.20	534.80	3.148	<.01
Sigma	498.31	66.96			

*See Table 2

Table 4

Comparison of differences between original discrimination learning and discrimination relearning for experimental and control groups in terms of mean differences in trials, mean difference in errors, and mean difference in time.*

	Diff. bt. original discrimination learning and discrimination relearning			
	Experimental	Control		
N	7	10	t	p
Mean difference in trials	11.40+	33.00-	2.50	<.05
Sigma	5.82	8.05		
Mean difference in errors	5.86+	25.10-	2.76	<.02
Sigma	22.04	20.80		
Mean difference in time (sec.)	417.70+	187.20-	3.24	<.01
Sigma	512.94	174.20		

*See Table 2

\- means less
\+ means more

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