THE USE OF ECS AS A UCS

By

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PREFACE

While proof reading the final copy of this paper, I began to recall the multitude of people who have contributed so heavily to its progress. Without their help it would never have been written.

I have spent a great deal of time thanking Dr. Neil Kent for many things. It seems almost anticlimactic to express gratitude for his unending desire to see this paper completed. Without his financial, moral, and professional support there would have been no thesis.

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The lessons in precision and accuracy which Dr. Larry Brown's meticulous corrections on draft after draft produced will serve me for many years to come. Yet, even more than the hours of labor I appreciate the sincere friendship with which they were delivered.

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CHAPTER I

STATEMENT OF THE PROBLEM

An animal subjected to electroconvulsive shock (ECS) shows difficulty in performing a newly learned response (Duncan, 1949). The apparent cause of this decrement in performance, termed "retrograde amnesia," has been the subject of controversy for the last decade (Gerard, 1955).

Interpretations by Duncan (1949), Gerard (1955), Madsen and McGraugh (1961), and Heriot and Coleman (1962) attempt to explain retrograde amnesia in terms of destruction of the consolidation of a stimulus-response association. The behavioristic interpretations of Coons and Miller (1960), Adams and Lewis (1962), Horvoka (1958) and Friedman (1953) maintain that the amnesia is not caused by a disrupted consolidation but may be understood in terms of competing responses.

The consolidation theory of retrograde amnesia originated when Duncan (1949) trained subjects to run from the dark to the light compartment of a shuttle box. He varied the interval between the response and onset of ECS from 20 sec. to 14 hr. All subject groups receiving ECS within 15 min. after the avoidance showed statistically greater decrement in performance than subject groups

receiving ECS after 15 min. Duncan interpreted the data in terms of a physiological consolidation in which the association of the avoidance response to the black box stimuli become "fixed" within 15 min. ECS administered prior to 15 min. effectively disrupted the consolidation process and resulted in a failure of the subject to associate the stimuli with the response.

In a 1955 variation of the Duncan experiment Gerard concluded that hamsters required up to 1 hr. to complete the consolidation as evidenced by the low scores made by subjects in the 1-hr. group. Both studies suggest that a physiological process is required to consolidate the learned association and the ECS interferes with this process. The extension of the consolidation time from 15 min. to 1 hr. may be due to the subject factor and should remain the problem of comparative psychology.

Two studies which followed provided a re-examination of the consolidation theory. In the first of these studies Adams and Lewis (1962) administered ECS 72 hr. prior to the learning of a response and found it as effective in producing a decrement in learning as ECS administered after the learning.

A consolidation theory is incapable of handling these data unless the consolidation is being formed 72 hr. prior to the presentation of the stimulus. The authors maintain that some explanation of the loss of the response is needed which does not require a consolidation of the stimulus-respose

association to start prior to the occurrence of the response.

Horvoka (1958) supplied an explanation in a study in which he attempted to use ECS as a trial terminator in a test of Guthrie's concept of reinforcement. A straight alley runway was designed with a bar crossing the entrance to the goal box. In order to reach food in the goal box the subjects were required to cross the bar, thereby depressing it. After the initial training bar depression brought about a convulsive current. Two combinations of intensity and duration were used to produce the convulsions. After several "self-introduced" convulsions the subjects failed to traverse the runway. The subjects receiving the less intense shock required more time to convulse and made fewer crossings than the subjects receiving the greater intensity. Horvoka attributed the failure of both groups to respond to the development of an avoidance. He explained the difference in the groups as due to the greater opportunity for the less intense shock group to acquire avoidance responses before convulsing.

The difference in the number of trials required for the different groups to stop responding poses a problem for Duncan (1949) in that the subjects receiving the more intense shock should have shown at least as much decrement in responding as the subjects receiving the less intense shock. Horvoka's avoidance interpretation allows for this difference as the subjects requiring more time to convulse are allowed a greater opportunity to associate stimuli with the convulsion. Of major importance to the problem discussed here is Horvoka's

presentation of a behavioristic interpretation.

This interpretation is not only compatible with the Adams and Lewis (1962) study in that a competing response could explain the observed decrement in responding shown by animals shocked prior to learning but brings the problem into the behavioristic theoretical realm. Coons and Miller (1960) replicated the Duncan study except that they set the aversive and amnestic effects of ECS in opposition to each other by requiring the subjects to stop performing an avoidance response. Subjects were taught to avoid shock in the dark compartment of a shuttle box by jumping into the light compartment or goal box. After 24 training trials the subjects were given painful shock when they entered the goal box, removed, and later returned to the goal box and given ECS. Groups were composed of subjects given ECS 20 sec. to 1 hr. after the electric shock in the goal box.

If ECS produces an avoidance as suggested by Horvoka, then the stimuli of the goal box would be paired with both painful and convulsive shock. If, however, ECS destroys a stimulus-response association as predicted by Duncan, then the subjects convulsed shortly after being punished for entering the goal box should have no fear of the goal box and should respond by avoiding the shock compartment. The findings showed that the subjects given ECS immediately after performing the punished response showed a greater tendency to avoid the goal compartment while those subjects given ECS 1 hr. after the response tended to make a signifi-

cantly greater number of crossings. The authors suggested that any amnesia which the ECS may have produced for the immediately preceding shock was overridden by the increased fear induced by the ECS.

Madsen and McGraugh (1961) and Heriot and Coleman (1962) also set the aversive and amnestic effects of ECS in opposition but failed to support the Coons and Miller findings. In the first of these studies subjects were lowered by a movable platform to within one inch of the grid in a shock compartment. When the subjects stepped to the grid from the platform, they completed a circuit and were shocked. Half of the experimental subjects received ECS within 5 sec. after performing the punished response. Controls were returned to their home cages. After 24 hr. rest all subjects were again lowered to the shock compartment. The subjects which had received both shock and ECS stepped from the platform with a significantly greater frequency than the controls.

In the second study Heriot and Coleman (1962) punished a bar press by administering two shocks to the subjects. The punished subjects were divided into treatment groups to receive ECS from 1 min. to 180 min. after the punishment. Two control groups were given a third grid shock 1 min. after the last of the original shocks. The subjects which received ECS were taken to another room and convulsed away from the Skinner box. When returned to the box and tested for retention of the fear of the bar, the ECS subjects responded while those subjects which had received the series of three painful shocks avoided

the bar. The decline in respondings followed the course that would be predicted from Duncan's study since subjects convulsed sooner after the punishment showed less avoidance to the bar.

The Heriot and Coleman study is of special interest in that subjects receiving ECS were convulsed in a stimulus situation entirely different from that in which they were tested. Studies by Friedman (1953) and Adams and Lewis (1962) would tend to cast doubt on the results of any experiment in which the pre-convulsive and test stimuli are different.

Friedman (1953) demonstrated that ECS and painful shock administered in the Skinner box after a bar press are both effective in inhibiting bar pressing. Subjects which were removed from the Skinner box and convulsed after a bar press showed no deterioration of response rate when compared to subjects which were neither shocked nor convulsed, but their performance was reliably different from the subjects given electric shock and those given ECS in the Skinner box.

Adams and Lewis (1962) further demonstrated the necessity of keeping the pre-convulsive and test stimuli the same. They trained two groups of subjects to avoid a dark compartment. Then half of the subjects received ECS in the shock compartment and half on a table 10 ft. from the avoidance apparatus. When the subjects were retrained, those receiving ECS in the shock compartment required more training trials to relearn the avoidance response than those subjects convulsed on the table.

The Adams and Lewis study presents an interesting problem in that the subjects were returned to the shock compartment and convulsed. If ECS is a fear provoking stimulus as claimed by Coons and Miller, then the effects of ECS should summate with the previously conditioned fear of the dark compartment and result in an increased avoidance behavior. However, Adams and Lewis' animals tended not to avoid. Duncan's consolidation interpretation would accurately predict the behavior of those subjects convulsed in the dark compartment but is incapable of handling the difference between the two groups as both groups received the same ECS and should have suffered the same degradation in their responding.

Adams and Lewis interpret their study in terms of a "conditioned convulsion." The authors contend that ECS serves as an extraordinarily strong unconditioned stimulus which produces the unconditioned response of a convulsion. Through classical conditioning the stimuli presented prior to the convulsion take on the role of conditioned stimuli and produce a conditioned convulsion which is incompatible with the avoidance response.

To support their contention that the loss of the response was not a result of the destruction of an association, the authors designed and ran another experiment in which the stimuli of the shock compartment were first conditioned to a convulsion and then the conditioned convulsive response was extinguished. In this experiment they first trained two groups of subjects to avoid the dark compartment. Then all

subjects were convulsed in the shock box. One group received 6 5-min. extinction periods in the shock compartment. On the sixth day all subjects were given 30 retraining trials. The number of avoidance responses were analyzed for both the extinction and the control groups.

A *t* test showed that subjects receiving extinction training gave a significantly greater number of responses than the non-extinguished subjects. Had the consolidation been destroyed, the subjects receiving the extinction training should have shown no improvement over the non-extinguished group. If ECS produces a fear response, then both groups of subjects would have shown avoidance responses with the subjects which received no extinction training showing the greater tendency to respond.

As the subjects in the non-extinguished group showed more difficulty in relearning, Adams and Lewis contended the stimuli of the black box were eliciting conditioned convulsions.

If ECS serves as an extraordinarily strong unconditioned stimulus, as claimed by Adams and Lewis (1962), then it follows that stimuli present prior to the convulsion may become conditioned to the convulsive response. Therefore, the ECS may not be destroying the association between the pre-convulsive stimuli and a response, but rather reconditioning the same stimuli to another response. This would suggest that what has been termed retrograde amnesia may not result from the loss of an association between a stimulus and a response, but rather from the establishment of a competing response.

In 1949 Estes and Skinner provided a procedure for measuring anxiety (fear) in experimental animals. Subjects were first presented with a light and buzzer followed by electric shock. When the light and buzzer were later introduced into a bar pressing situation, the subjects showed a decrement in their bar pressing. The authors interpreted their findings as indicating the development of a response to the light-buzzer complex incompatible with bar pressing.

If a stimulus-response association is destroyed by ECS, it would be impossible for a subject to learn a response to any stimuli presented prior to ECS. If, however, ECS is capable of conditioning a response incompatible with performing a previously learned response, as both the fear-conditioning and conditioned-convulsions interpretations would suggest, the response should be incompatible with bar pressing and could be measured by using a procedure like that of Estes and Skinner.

Explicitly, the present study was designed to test the hypothesis that a measurable response can be conditioned to a neutral stimulus when ECS is used as an unconditioned stimulus.

If the neutral stimulus paired with ECS becomes effective in eliciting a conditioned response, a significant Treatments X Periods effect could appear in an analysis of variance. Although the analysis includes other F tests, they are not to be interpreted as supporting or casting doubt on the hypothesis that a measurable response can be conditioned to

a neutral stimulus which precedes ECS. All *F* ratios tested other than the Treatments X Periods effect may be used in hopes of developing areas for further research.

CHAPTER II

METHOD

Subjects

Fifty male rats of the Sprague-Dawley strain from the Oklahoma State University colony were used as subjects. The animals were approximately 250-300 days old and had previously been used as subjects in a study of escape learning in which a water maze was employed.

Apparatus

Convulsive Apparatus. The apparatus used to deliver ECS was a modification of the ECS generator described by Hayes (1948). The simplified generator delivered 0.05 milliamperes for 0.2 sec. through alligator clips attached to the subjects' ears. The light and buzzer (CS), presented for 45 sec. prior to the ECS, were electrically timed, and their termination served to activate the ECS delivery capacitor. The CS timer was later reset to 30 sec.

Testing Apparatus. The Skinner box was a modified styrofoam ice cooler measuring approximately $9\frac{1}{2}$ in. X 12 in. X 9 in., inside dimensions, with a 3 in. X 6 in. glass window set in the top. All surfaces were painted flat black. The

bar was centered on one of the 9 in. walls approximately 2 in. above the floor, which was made of brass rods 5/16 in. in diameter spaced 5/8 in. apart. The food receptacle was secured to the walls midway between the bar and the 12 in. wall to the right of the bar. The Skinner box was housed in a sound-deadened closet approximately 4 ft. X 4 ft. X 6 ft., outside dimensions. A one-way glass set in the closet door exposed a mirror which allowed the experimenter to observe the subjects through the window in the Skinner box.

Above the Skinner box the light and buzzer were secured to the flat black surface of the three layers of celotex which lined the closet walls and helped deaden the sound. The hum of the fan, which circulated air throughout the closet and Skinner box, produced a constant sound and also helped in minimizing sounds from outside the closet.

Depression of the bar closed a microswitch which completed a circuit. This activated two electrical counters, a cumulative recorder, and the timer for a Foringer pellet dispenser. The dispenser delivered a pellet on a shcedule determined by a cellulose tape. The four tapes used in this experiment were set for 15-sec., 30-sec., 1-min., and 2-min. variable interval schedules respectively.

Procedure

Pretraining and Adaptation. The pretraining and adaptation period lasted 32 da. Each subject received one session in the Skinner box each day and was then returned

to the home cage and given free feeding for 2 hr. The subject was under 22-hr. food deprivation when it was placed in the Skinner box for its daily time.

On each of days 1 and 2 the subjects were given a 10-min. session in the Skinner box. During this time food was available in the food receptacle. The purpose of days 1 and 2 was to adapt the subjects to the Skinner box and feeding from the food receptacle.

Days 3 and 4 were used to train the subjects to bar press for food reward. Each subject was given 20 min. a day in the Skinner box. The subjects were first trained to associate the click of the pellet dispenser with the food reward and then through successive approximation were taught to press the bar for food. Eight subjects were eliminated on day 4 for failing to bar press.

A 15-sec. variable interval (VI) schedule was introduced on day 5. The subjects received one 30-min. session of training on this schedule.

On days 6 and 7 the VI was extended to a 30-sec. interval. The subjects received one 30-min. training period a day. The VI was increased to 1 min. on day 8. The subjects received one 30-min. practice period on this schedule.

On the following day, day 9, the VI was extended to 2 min. For the remainder of the experiment the subjects were given one 30-min. session a day on a 2-min. VI schedule.

From days 5 through 9 extra reinforcements were given as needed to maintain responding. After day 9 no extra reinforce-

ments were given.

On days 10 through 18 the subjects were given practice on the 2-min. VI schedule. In this phase of the pretraining no extra reinforcements were given. Subjects which were unable to adapt to the low frequency of reinforcement were eliminated. By day 18 seven subjects were dropped from the study. On day 19 alligator clips were attached to the subjects' ears before they entered the Skinner box for their 30-min. practice session on the 2-min. VI schedule. The clips were replaced during the session if the animals removed them from their ears. This practice was followed from day 19 to day 27 in an attempt to adapt the subjects to wearing the alligator clips. By day 27 the subjects were not showing a noticeable decline in the number of replacements of the clips they required.

As the subjects failed to adapt to the alligator clips, permanent implants were made in their ears by use of wound clamps. To each clamp was attached a lead which extended along the animal's back and was taped to him by a band of $\frac{1}{2}$-in. adhesive tape wrapped around the body immediately behind the front legs.

From day 28 to day 33 the animals were given one 30-min. session a day in the Skinner box on a 2-min. VI schedule. By day 33 the idea of implanted leads was discarded as the subjects tore the leads from the wound clamps.

Alligator clips were flattened and reshaped to fit the wound clamps in the subjects' ears. These were used through-

out the remainder of the experiment. No further attempt was made to adapt the subjects to any type of ear clamp. This concluded the adaptation and pretraining phase of the experiment.

Conditioning and Test Trials

On day 33 the subjects were divided into four treatment groups on the basis of their average number of responses on days 31 and 32. The groups were selected so that the average number of responses for each group was approximately equal. (a) The CS group, composed of seven subjects, received the blinking light and buzzer for 45 sec. (b) The ECS group, composed of 10 subjects, received the ECS at the end of the 45-sec. period. Of the 10 subjects starting in this group, 4 died. (c) The none group, composed of seven subjects, received neither CS nor ECS during the 45-sec. period. (d) The CS-ECS group received the blinking light and buzzer for 45 sec. following by ECS. Of the 10 subjects in this group, 6 died.

On days 33 through 37 the subject was returned to the Skinner box within $7\frac{1}{2}$ to $8\frac{1}{2}$ hr. after his daily bar pressing trial to receive the appropriate treatment. This was followed in $7\frac{1}{2}$ to $8\frac{1}{2}$ hr. by a second treatment in the apparatus. During the treatment periods the subjects were separated from the bar and food receptacle by a plexiglass partition.

On day 35 of the experiment the treatment time in the apparatus was reduced from 45 sec. to 30 sec. for all subjects

as the animals in the CS group were struggling with the clips and leads.

Once daily from day 34 to day 38 each subject was allowed 30 min. of free responding in the Skinner box. A record was kept of the number of bar presses made during each successive 5-min. period. During the fourth 5-min. period a light and buzzer (CS) were presented. This 5-min. period composed the test period (CS period). The 5-min. periods before and after the CS period were designated BL_1 and BL_2 and served as base lines for the evaluation of the bar pressing performance during the CS period.

CHAPTER III

RESULTS

The daily mean response rate for each treatment group during periods BL_1, CS, BL_2 is given in Table I. These data were analyzed in a Treatments X Days X Periods analysis of variance with unequal numbers (Winer, 1962, pp. 319-337, 374-378). The design involved repeated measures on two factors, as subjects in the treatment groups were measured on the same task across both the time periods and days. The analysis is summarized in Table II.

It can be seen that no differences due to either the Treatments or Days were significant. However, the F ratios for the Periods effect was statistically reliable. No other effects or interactions were found to be significant.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The data would appear to support the finding (e.g., Duncan, 1949; Gerard, 1955) that subjects demonstrate no learned behavior to pre-convulsive stimuli. The finding that a decrement in responding occurred during the CS period suggests that the light and buzzer served to inhibit bar pressing irrespective of the training history of the animal.

Conclusions of the present study must be qualified in light of a number of design and procedural considerations. First, the effect on the present results of exposure to different schedules of reinforcement in a previous water maze study cannot be evaluated. Further, the poor physical condition of the subjects was obvious and no doubt contributed to the disproportionate number of deaths in the ECS groups. Moreover, the series of changes in the lead placement may have influenced the results in an unpredictable manner.

Subjects were assigned to treatment groups according to their response rates in such a fashion as to hold the mean number of responses for each treatment group approximately equal. With only half of the ECS subjects completing the experiment, the assumption that the means for the four treat-

ment groups remained equal is questionable. However, the failure of the F test to separate the groups would argue against this possibility.

When these possibilities and the small number of subjects employed are considered, temperance in accepting or rejecting any conclusions based upon this study would be justified. To the writer's knowledge no attempt has been made prior to this study to control the pre-convulsive stimulus situation by presenting a specific CS whose presence or absence may be controlled by the experimenter. Such a procedure allows the experimenter an opportunity to compare the subject's response to the pre-convulsive stimuli with performance in the absence of the stimuli.

In the present study the CS may have been of such a nature as to elicit interfering responses in the control subjects. A less intense CS might provide a better test for the development of a conditioned response, with ECS employed as the UCS, and should serve as grounds for further research.

CHAPTER V

SUMMARY

Experiments over the last decade have repeatedly shown that animal subjects subjected to electroconvulsive shock (ECS) show a decrement in performance of a newly learned response. Explanation for this phenomenon has centered in two broad categories: those advocating a physiological fixation process and those suggesting some form of a competing response.

Duncan's (1949) consolidation hypothesis serves as a typical example of the first group. By following an avoidance response with ECS, Duncan demonstrated that a convulsion administered within 15 min. after the response was effective in eradicating the response when the subjects were returned to the avoidance apparatus. He contended that ECS served to disrupt the consolidation of the association between the apparatus stimuli and the avoidance behavior.

The second, or behavioral, approach is characterized by the hypothesis of Adams and Lewis (1962) that ECS serves as a UCS to condition pre-convulsive stimuli to responses, such as convulsions, incompatible with performance of avoidance responses. In support of their hypothesis Adams and Lewis trained subjects to avoid the dark compartment in

a two compartment shuttle box. After performing the response half the subjects were convulsed in the shock box and half on a table 10 ft. from the shuttle box. The findings showed that the subjects convulsed in the shock box failed to respond while subjects convulsed away from the apparatus continued to make the avoidance response.

The present study was designed to test the hypothesis that a measurable response can be conditioned to a neutral stimulus when ECS is used as an unconditioned stimulus.

Subjects which had previously been trained to press the bar in a Skinner box on a 2-min. variable-interval (VI) schedule reward were given training in one of four treatment groups: a) CS - ECS, b) CS, c) ECS, d) neither CS nor ECS (None). A light-buzzer complex served as the CS. All subjects wore the ear clips through which ECS was administered and received equal exposure to the apparatus.

When the CS was later presented to the subjects in the bar-pressing situation, it failed to produce a statistically greater bar-pressing decrement in the CS-ECS subjects than in the three control groups.

The data from the present study were interpreted to lend tentative support to the consolidation or fixation hypothesis. Due to procedural and design considerations caution was recommended in accepting or rejecting the hypothesis on the grounds of this study.

TABLE I

DAILY MEAN RESPONSE RATES FOR PERIODS BL_1, CS, and BL_2

	DAY I			DAY II			DAY III			DAY IV			DAY V		
	BL_1	CS	BL_2	BL_1	CS	BL_2	BL_1	CS	BL_2	BL_1	CS	BL_2	BL_1	CS	BL_2
CS-ECS	79.5	33.5	75.8	108.0	106.5	94.8	101.5	50.5	73.5	76.8	40.8	50.5	59.0	17.2	25.0
ECS	178.2	98.0	124.2	98.5	77.5	67.8	122.5	118.7	117.7	118.0	95.0	134.7	121.2	97.2	92.7
CS	141.6	136.3	122.1	114.3	110.3	108.4	145.4	111.3	129.0	153.3	92.7	115.9	130.6	117.4	132.6
None	127.6	93.4	103.4	150.7	139.7	100.7	124.1	104.1	96.7	162.3	113.1	114.7	140.1	93.7	111.3

TABLE II

ANALYSIS OF VARIANCE FOR DAILY MEAN RESPONSE RATES

Source of Variation	df	MS	F	P
Between Ss	23	40208.70		
Groups	3	48249.43	1.2371	3.49
Error Groups	20	39002.59		
Within Ss	336	1980.56		
Days	4	1348.775	.778	2.49
Groups days	12	5918.775	1.73	1.88
Error days	80	3416.6		
Periods	2	30325.00	21.48	3.23
Groups periods	6			2.34
Error periods	40	1411.92		
Days periods	8	1453.41	1.47	2.00
Groups days periods	24	1125.896	1.137	1.59
Error days periods	160	990.2		
TOTAL	359			

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