THE EFFECTS OF ELECTROCONVULSIVE SHOCK ON THE ACTION OF A REINFORCING STIMULUS¹

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Three experiments sought to evaluate the effect of electroconvulsive shock on the action of a reinforcing stimulus. In all experiments behavior was maintained on a 2 min variable interval schedule for food reinforcement. Foot shock at the termination of a buzzer stimulus served as the reinforcing stimulus for conditioned suppression during the ensuing buzzer interval. Omission of foot shock at the termination of the buzzer stimulus was followed by normal responding (no conditioned suppression) during the next buzzer interval. In Exp I electroconvulsive shock followed foot shock at varying time intervals. In the first subsidiary experiment electroconvulsive shock followed an unreinforced buzzer stimulus at varying time intervals. In the second subsidiary experiment electroconvulsive shock followed foot shock at varying time intervals and an additional buzzer stimulus was sounded between the termination of foot shock and the onset of electroconvulsive shock. These three experiments demonstrated that electroconvulsive shock invariably abolished the effects of the reinforcing stimulus if it followed conditioning by no more than 10.0 sec and never had an effect if it followed conditioning by 12.5 sec or more; electroconvulsive shock was not acting as a reinforcing stimulus in this situation.

Several traumatic cranial events, particularly electroconvulsive shock (ECS), have been shown to prevent or reduce the modification of a response by a reinforcing stimulus. Glickman's (1961) review of the experimental evidence suggests that the effect of ECS on conditioning is related to a number of variables, *e.g.* the nature and severity of the trauma and a diversity of relationships between the traumatic event and the reinforcing stimulus, *i.e.*, conditioning.

The present experiments were designed as a step toward an experimental analysis of the effects of ECS upon the action of a reinforcing stimulus. A technique was developed which allowed each subject to serve as its own control and permitted repeated observations on each subject. The experiments meet several essential characteristics for any experiment seeking to evaluate the effects of ECS upon the action of reinforcing stimuli. First, a single reinforcing

stimulus must condition an unequivocal and reproducible change in behavior when presented to the subject. Second, the conditioned change produced by the reinforcing stimulus must occur as a deviation from a known baseline which is sensitive to the effects of various variables and is under experimental control. Third, the conditioned change produced by the reinforcing stimulus should be similar to the change which would be produced if an ECS were aversive. Fourth, no events, unless both specifiable and manipulable, should intervene between the reinforcing stimulus and the traumatic ECS.

With these four conditions met it is possible to evaluate the effects of ECS on the action of a reinforcing stimulus. Experiment I below demonstrates the attainment of the desired degree of experimental control. Several additional manipulations extended the generality of the results.

EXPERIMENT I

Subjects

Two male rats of mixed genetic background were selected from the colony maintained at the University of North Carolina. They were between 80 and 100 days old at the beginning and 290 and 310 days old when the experiment was completed.

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Apparatus

A Gerbrands operant conditioning box for rats, with a system of pulleys attached to hold an electrode cord in place, was placed in a sound insulated chamber. A blower fan attached to the chamber masked external noise and provided ventilation. The box, which was dark before and after each session, was illuminated by two 3 w pilot lamps during the experimental session. The grid floor was connected to a commercial shock source through a grid scrambler (Grason-Stadler E1064GS). The shock source allowed foot shocks of adjustable intensity and duration to be presented. Food reinforcement consisted of 45 mg Noyes food pellets delivered by a pellet dispenser. A relay click and the pellet dispenser solenoid thump were contiguous with food delivery. The chamber also contained a buzzer of adjustable intensity for auditory stimulation.

A cranial electrode cord, shielded to prevent destruction by the subject, led from the box to the power supply used to present the electroconvulsive shock (Hayes, 1948). The output of the ECS power supply was set at 1200 v ac which resulted in a current of 45 ma across the rat. An automatic timer set ECS duration at 1 sec. Preliminary tests indicated that a shock of this intensity and duration produced an electroconvulsive seizure with both tonic and clonic extensor phases (Weissman, 1963).

All stimuli presented were determined by standard relay circuits kept in a separate room. A cumulative recorder recorded all responses, reinforcements, and other changes in experimental conditions. Counters and time meters recorded both times and responses separately for each of the various experimental conditions.

Procedure

All subjects were given a permanent cranial electrode which just penetrated the skull. To accomplish this two screws were turned just through the skull, so their tips presumably rested upon but did not penetrate the dura mater, at the intersection of the coronal and saggital sutures. Animals which showed signs of rupture of the dura mater (*e.g.*, excessive bleeding) at the time of operation were immediately discarded. As neither the operative procedure nor subsequent electroconvulsive

shocks produced any apparent permanent effects on behavior, post mortem examinations of the subjects' brains were not carried out. Therefore, an intact dura mater may only be presumed. The leads of a standard cranial electrode were then attached to the heads of these two screws and the electrode was fixed with cranial cement. After surgery the subjects were placed on a free feeding regimen for two weeks.

They were then deprived to approximately 65% of free feeding weights and feeder trained. The subjects were then conditioned to depress a lever by making food reinforcement contingent on lever depression. All subjects were given 100 reinforcements per day on a continuous reinforcement schedule, that is, one reinforcement for each lever depression, until response rate on the continuous reinforcement schedule was sufficient to insure responding on a variable interval schedule of 2 min (VI 2); *i.e.*, a single response was rewarded every 2 min on the average. Subjects were run on the variable interval schedule for 90 food reinforcements each day until a stable performance was obtained (at least 30 days). The electrode cord was introduced on the first day of training and was present throughout the experiment.

When VI performance had stabilized, the buzzer which served as the pre-shock stimulus for an Estes-Skinner procedure (Estes and Skinner, 1941) was introduced. Its intensity was adjusted until it obviously decreased responding while it was sounded, but did not disrupt responding during its absence. This was done to be certain that the subject was aware of the buzzer and to allow the experimenters some basis for assessing the effects of the buzzer alone. The pre-shock stimulus consisted of sounding the buzzer for 2 min. The buzzer was presented on a VI 8 min schedule with three intervals (6.0 min, 11.7 min, 6.3 min). The buzzer was presented without shock on this VI schedule until all unconditioned responses to the buzzer habituated, that is, the rate of responding had returned to the pre-buzzer level both in the presence and in the absence of the buzzer.

After unconditioned responses to the buzzer habituated and performance for food reinforcement had stabilized again, a foot shock was paired with termination of the buzzer. An attempt was made to find a shock intensity

and duration for each subject that would just produce the Estes-Skinner effect (complete suppression) during the buzzer without disrupting the baseline behavior. In early sessions, intensity was varied from .6 to 3 ma and duration from .5 to 3 sec. Permanent intensity and duration values were determined when each subject exhibited the desired behavior. Occasionally a higher value of both intensity and duration was used for one shock to reinstate complete suppression during the buzzer interval.

Subjects were run with shock paired with buzzer termination until responding suppressed during the buzzer interval and the food-reinforced behavior in the absence of the buzzer was again stable (at least 45 days). The foot shock was then withdrawn from the Estes-Skinner procedure and the conditioned suppression was allowed to extinguish. This procedure (conditioning followed by extinction) was repeated until a single foot shock, the reinforcing stimulus, paired with termination of a buzzer interval, was sufficient to suppress responding completely during the next buzzer interval and a single buzzer presentation without foot shock was usually sufficient to extinguish the effect.

In the experiment proper, each subject was run daily on a VI 2 min schedule with the buzzer of the Estes-Skinner procedure, presented on a VI 8 min schedule, superimposed on this food reinforcement baseline. The first buzzer interval of a particular session was never introduced until after the subject began to respond on the food reinforced baseline. On a day selected for an observation the subject was run to the middle of the session (the most stable period) without foot shock. At the end of the selected buzzer interval of this session, subjects were given a single foot shock followed at varying time intervals by ECS. They were then returned to their home cage. Control observations were obtained by removing the subject from the experimental chamber at varying time intervals after foot shock without presenting ECS. The following day the subjects were returned to the box and the session was begun. After performance became stable on the VI 2 min schedule within the session, the buzzer was presented to test the effect of ECS on the expected Estes-Skinner effect. This procedure was repeated on all subjects to obtain multiple observations.

Table 1 presents a summary of the foot shock-electroconvulsive shock intervals used and the number of observations obtained from each subject.

RESULTS

Figure 1 illustrates stylistically the behavioral observations relevant to the effects of ECS on the action of the reinforcing stimulus. If foot shock, the reinforcing stimulus, were not followed by ECS, suppression occurred during the next buzzer interval (*e.g.* Fig. 1, part 3). When foot shock (first arrow, Fig. 1, part 1) was followed by ECS (second arrow, Fig. 1, part 1) at least two outcomes were possible. When ECS interfered with the action of the reinforcing stimulus, responding occurred during the next buzzer interval (*e.g.* Fig. 1, part 2). When ECS had no effect on the action of the reinforcing stimulus, responding did not occur during the next buzzer interval. A third possibility, that ECS could augment the action of the reinforcing stimulus and thus produce suppression during the buzzer interval and a disruption of the food-reinforced baseline, was never observed.

The results of all ECS manipulations are summarized in Table 1. Selected cumulative record segments showing the data observed are presented in Fig. 2. Only small segments of the records are shown since they contain the pertinent information. In every case the cumulative record segment shows the beginning of a session. The first record segment of each pair contains the comparison interval which is marked by (↓). The second record segment of each pair contains the test interval which is also marked by (↓). The other buzzer

Fig. 1. A stylized representation of the range of effects produced as observed on cumulative records of the performances.

intervals which appear in the records were those presented on the VI 8 min schedule. None of the buzzer intervals appearing in these record segments was paired with a foot shock. However, the test buzzer interval ($\downarrow$ in second record segment of each pair) was always the first buzzer interval to follow foot shock and ECS. The buzzer interval which was paired with foot shock and followed by ECS occurred at the end of the first session of each pair and is not shown in the figure.

The first column of Fig. 2 shows the results of the ECS manipulations for subject 3. The ratios of the number of responses during the comparison buzzer intervals to the number of responses during the test buzzer intervals are presented in Table 1. When the time interval between foot shock and administration of ECS was 5, 10, or 11 sec, responding occurred during the comparison and the test buzzer intervals. When the interval was 12.5, 15, or 30 sec, responding was suppressed during the test buzzer interval.

The second column of Fig. 2 shows the results of ECS manipulations for subject 13. These results are also summarized in Table 1. For subject 13 responding was observed during the comparison and the test buzzer intervals with foot shock-ECS intervals of 5, 7.5, and 9 sec. Two observations were obtained where the interval was 10 sec. In one instance, complete suppression was observed; the other indicated no suppression. When the interval between foot shock and ECS administration was 11, 12.5, or 15 sec, responding was suppressed during the test buzzer interval.

The results of this experiment can be summarized as follows: when the time interval between presentation of the reinforcing stimulus and administration of ECS was 9.0 sec or less, electroconvulsive shock abolished the action of the reinforcing stimulus. When the time interval was 12.5 sec or more, ECS had

no effect on the action of the reinforcing stimulus. The foot shock-ECS intervals between 9.0 and 12.5 sec appeared to delimit a "transition zone" as the effect of ECS at these times varied from subject to subject and on one occasion between observations on the same subject.

DISCUSSION

The temporal relation between the presentation of the reinforcing stimulus and a subsequent seizure produced by ECS is an exceedingly important determinant of ECS effect on the action of the reinforcing stimulus. The results of Exp I suggest that a critical conditioning-ECS interval of about 3 sec exists. Electroconvulsive shock always abolished the action of the reinforcing stimulus if the conditioning-ECS interval was less than 9.0 sec, and had no effect if the interval was greater than 12.5 sec. The results of Exp I strongly suggest that, given the highly controlled conditions of the present experiment for both conditioning and ECS procedures, a constant minimum time must occur between them if the effects of conditioning are to be observed on subsequent behavior.

SUBSIDIARY EXPERIMENTS

Subjects

Two male rats of mixed genetic background were used. Both had served in Exp I.

Apparatus

The apparatus was the same as that used in Exp I.

EXTINCTION

The extinction experiment was undertaken as an additional control for possible effects

Table I

The effect of various intervals between foot shock and electroconvulsive shock on responding during the sounding of the buzzer as shown by the number of responses during the comparison buzzer interval over the number of responses during the test buzzer interval.

Subjects	foot shock-ECS interval in seconds							
	0.5	7.5	9.0	10.0	11.0	12.5	15.0	30.0
3	$\frac{24}{23}, \frac{22}{27}$			$\frac{12}{20}$	$\frac{19}{16}$	$\frac{16}{0}$	$\frac{21}{0}$	$\frac{21}{3}$
13	$\frac{9}{13}$	$\frac{8}{9}$	$\frac{5}{14}$	$\frac{13}{15}, \frac{5}{0}$	$\frac{10}{1}$	$\frac{6}{1}$	$\frac{6}{1}$

Fig. 2. Segments of cumulative records illustrating the results of Exp I for subject 3 and subject 13. A segment of cumulative record from each of the two relevant sessions is indicated by a dark line linking the two cumulative record segments. The number to the left of each pair of records indicates the time interval between foot shock (2 sec, 4 ma) and electroconvulsive shock, for that electroconvulsive shock manipulation. The buzzer intervals which were compared in the determination of the results are marked on the figure by $\downarrow$. Hash marks on the records mark reinforcements on the food maintained baseline. The pen was deflected downward and held down for the duration of each buzzer interval. Reinforcements occurring during the buzzer interval show as upward deflections of the pen.

of ECS as a reinforcing stimulus, which might contaminate another reinforcing stimulus. Specifically, the experiment was designed to demonstrate any aversive properties of ECS which might be acting in the present experiments.

Procedure

This consisted of pairing foot shock with the termination of a selected buzzer interval. Approximately 6 min later, within the same session, the buzzer was presented again but foot shock, the reinforcing stimulus, was omitted. This unreinforced buzzer interval was then followed by ECS at either 5 or 15 sec. Control observations with no foot shock and no ECS were also obtained.

RESULTS

Part A, Fig. 3 shows cumulative record segments illustrating the results. Foot shock occurred at (sh) and electroconvulsive shock occurred at the end of the last buzzer interval of the first session of each pair (at first ↓ of each pair). The first buzzer interval of the next session (second ↓ of each pair) served as the test buzzer interval. As can be seen, ECS had no effect on the extinction of the effects of the reinforcing stimulus. This was true at both time intervals (5 and 15 sec). The same result was obtained when electroconvulsive shock was omitted.

DISCUSSION

The results of the extinction experiment are quite suggestive. It appears unlikely that a single ECS acts as an aversive stimulus in this situation since an aversive electric shock could be expected to produce effects similar to those seen with foot shock. If this were the case, extinction would not have occurred in this experiment when the interval between the end of the buzzer interval and ECS administration was 5 sec. These results are quite consistent with those obtained in Exp I. It appears that under these conditions ECS affects behavior only when it follows a reinforcing stimulus within a short time interval (12.5 sec or less). In the present experiment, following an unreinforced buzzer interval with ECS has the same effect as presenting an unreinforced buzzer interval.

Fig. 3. Segments of cumulative records illustrating the results of the subsidiary experiments. Hash marks on the records mark reinforcements on the food maintained baseline. The pen was offset downward for the duration of each buzzer interval. Part A illustrates the results of the extinction experiment for subject 3. Foot shock occurred at sh. Foot shock was followed by an extinction buzzer interval. Electroconvulsive shock followed this extinction interval and is marked by ↓. The numbers to the left of the dark line indicate the time interval between the end of the extinction interval and electroconvulsive shock. The second ↓ marks the test interval. Part B illustrates the results of the electroconvulsive shock with "practice" experiments for subject 3 and subject 13. The first ↓ of each pair marks electroconvulsive shock. The second ↓ of each pair marks the test interval. The last hash mark of each comparison buzzer interval marks the administration of foot shock. The buzzer was sounded again from this point until the administration of electroconvulsive shock.

ECS WITH "PRACTICE"

Procedure

This procedure was a variation of that used in Exp I. The termination of a selected buzzer interval was paired with a foot shock. Immediately after termination of the buzzer and foot shock the buzzer was sounded again. Electroconvulsive shock was presented at various time intervals after the buzzer-shock pairing was terminated and after the onset of the subsequent buzzer sounding.

RESULTS

Part B, Fig. 3 shows the results for subject 3 and subject 13. The time interval indicates the amount of time between administration of a 2-sec, 4-ma foot shock and occurrence of ECS. Electroconvulsive shock always occurred during the buzzer interval which was begun at the termination of foot shock. Since this second buzzer interval never lasted more than 12.5 sec it does not show up well on the records. The last upward pen deflection of each comparison buzzer interval (the first ↓ of each pair) marks the termination of the first buzzer interval and administration of foot shock. The resetting of the pen to its baseline position marks ECS administration. The space between these two points shows the duration of the "practice" buzzer interval. Responding was never observed during the buzzer interval after foot shock but before ECS for either subject 3 or subject 13. When the interval between foot shock and ECS was 12.5 sec for subject 3 or 11.0 sec for subject 13, responding was suppressed during the test

buzzer interval. The ratio of responses during the comparison buzzer interval to responses during the test buzzer interval was 20:2 for subject 3 and 10:1 for subject 13. When the interval between foot shock and ECS was 11.0 sec for subject 3 or 9.0 sec for subject 13 suppression was not observed during the test buzzer interval (ratios: 19:16 for subject 3 and 14:13 for subject 13).

DISCUSSION

The results of this experiment are, potentially, of great theoretical interest. They raise the question of how a seizure caused by an electric shock can abolish the action of a reinforcing stimulus whose behavioral effects were observable before electroconvulsive shock was presented. Further, the limited results of these experiments suggest that the practice of the conditioned suppression had no effect on the critical duration of the conditioning-electroconvulsive shock interval.

REFERENCES

- Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **29**, 390-400.
- Glickman, S. E. Perserverative neural processes and consolidation of the memory trace. *Psychol. Bull.*, 1961, **58**, 218-233.
- Hayes, K. J. Cognitive and emotional effects of electroconvulsive shock in rats. *J. comp. physiol. Psychol.*, 1948, **41**, 40-61.
- Weissman, A. Effect of electroconvulsive shock intensity and seizure pattern on retrograde amnesia in rats. *J. comp. physiol. Psychol.*, 1963, **56**, 806-810.

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