## Amnesic and Punishing Effects of Electroconvulsive Shock

Abstract. *Rats learned to avoid a place where they were repeatedly given electroconvulsive shock treatments, but the learning was slow in comparison with that obtained with subconvulsive shock. Convulsive shock given 5 seconds after administration of subconvulsive shock retarded place-avoidance learning.*

Rats given electroconvulsive shock (ECS) shortly after receiving training on a task tend to perform poorly on subsequent retention tests. Among the many interpretations of this effect the most generally accepted hypothesis is that the shock interferes with consolidation of the memory trace (*1*). There is some evidence, however, to support the view that these shock treatments are punishing and that rats learn to avoid making responses that are followed by shock (*2*). A third interpretation proposed recently (*3*) suggests that electroconvulsive shock impairs the performance of previously learned responses because cues present during treatments and subsequent testing arouse competing responses such as crouching and huddling which interfere with the performance of the previously learned response.

In previous studies with a one-trial passive avoidance learning task, we (*4*), as well as others (*5*), found no evidence to support either the punishment hypothesis or the "competing response" hypothesis. Rats failed to inhibit a previously punished response if electroconvulsive shock was administered shortly after the training trial. However, in another study (*6*) with a similar passive avoidance task but *repeated* training trials, post-trial ECS treatments retarded learning, but rats given only shock treatment tended, with repeated treatments, to cease making the response which was followed by shock. The significance of this finding lies in the fact that recent studies supporting the amnesia hypothesis have generally used only one shock treatment, while those supporting the punishment and the "competing response" hypotheses have used repeated treatments.

The results of the two experiments reported here provide additional support for the conclusion that electroconvulsive shock has *both* an amnesic *and* a punitive effect and that the former cannot, as has been claimed (*3*), be readily explained by the latter. The results of the first study indicate that the punishing effects of such shock are not due simply to conditioning of competing responses. Rats learned to avoid an alley leading to a place in a maze where they were given shocks. The rate of place-avoidance learning by rats given electroconvulsive shock treatments as punishment was considerably slower than that of rats punished with subconvulsive shock.

Nineteen water-deprived Sprague-Dawley rats (age 110 to 120 days) were first given 8 days of preliminary training in an alley T-maze. The goal boxes at the ends of the arms, each of which contained water bottles, differed in brightness, shape, and texture. The left goal box was white, circular, and was completely lined with fine-mesh screening. The right goal box was black, square, and was lined with coarse hardware cloth. The color and texture of the boxes extended to the choice point. The starting alley was unpainted. Guillotine doors at either side of the choice point and at the entrance to the goal boxes were used to control preliminary training choices and to prevent retracing. On days 1 and 2 the subjects were placed directly into the goal boxes and allowed to drink for 10 minutes in each. On days 3 through 6, the subjects were placed in the starting box and allowed to run to a goal box for a 30-second water reward. Only one trial was given on each of these days. On days 7 and 8, subjects ran four trials per day with an intertrial interval of approximately 30 minutes. To insure equal exposure to the goal boxes, the rats were given free choices on half of the trials and entrances were controlled (by closing the doors to the previously chosen alleys) on the remaining trials. On days 3 through 6 goal box entrances were equalized over the four trials. On days 7 and 8 the rats were allowed to enter each box twice on each day. On day 9, each rat was placed directly into a goal box, and after 5 seconds was given either an electroconvulsive shock (35 ma; $N = 10$) or a subconvulsive shock (2 ma; $N = 9$) to the pinnae via modified alligator clip electrodes. Half of each group was shocked in one goal box and half in the other. The groups were matched on the basis of the rats' goal box preferences on the free choice trials during the earlier training. Of the rats with goal box preferences, half were shocked in the preferred goal box and half were shocked in the nonpreferred goal box. On day 10, subjects were given one trial in the maze. Subsequently, experimental treatment and single maze trials were given on alternate days. The animals were never shocked on any day in which they were given a test trial in the maze. Subjects were given water in home cages for 15 minutes each day, 4 hours after the shock treatment or maze trial. Goal box choices and latencies were recorded.

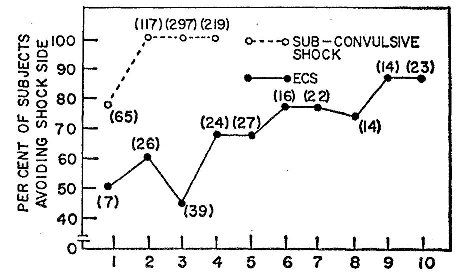


Fig. 1. Percentage of choices of nonshock goal box and median latencies in seconds (in parentheses) on each test trial, for rats that received subconvulsive shock or electroconvulsive shock (ECS). Abscissa: trials.

After the first subconvulsive treatment, seven of nine subjects chose the goal box in which shock was not received (see Fig. 1). On the second test trial and on two subsequent trials, all subjects that received subconvulsive shock chose the nonshock side ($p < .01$). The goal-box choices of subjects receiving convulsive shock were not affected for several trials. However, these subjects chose the nonshock goal box with increasing fre-

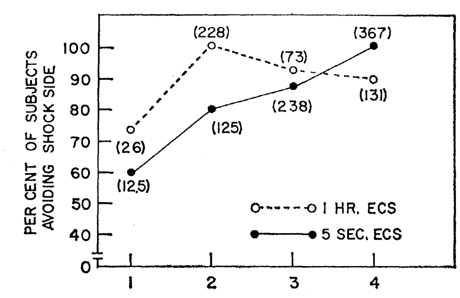


Fig. 2. Percentage of choices of nonshock goal box and median latencies in seconds (in parentheses) on each test trial, for rats that received 1-hour-delayed electroconvulsive shock (ECS) or early (5-second-delayed) ECS. Abscissa: trials.

quency until, on trials 9 and 10, seven of the eight remaining subjects chose the nonshock side (*7*). Throughout the test trials the latencies of the group given subconvulsive shock were significantly greater than those of the group given convulsive shock. For trial 1, a Mann-Whitney U test indicated a difference in latencies between the two groups significant beyond the .02 level. In the group given convulsive shock the median latency for test trial 1 (7 seconds) was identical to the median latency of the last day of pretraining. The subjects that received subconvulsive shock, however, showed a sharp increase in latencies ($p < .02$, sign test) on the first test trial. These findings indicate that active avoidance of the shock goal box develops with repeated convulsive-shock treatments, but at a rate not nearly as rapid as that found with subconvulsive shock of a much lower intensity. The absence of active avoidance or increase in latency after a single electroconvulsive shock is consistent with previous results (*4, 5*). In view of the fact that several experiments have shown amnesic effects of a single convulsive-shock treatment (*1, 4, 5*) our findings suggest that it is highly unlikely that the amnesic effect of electroconvulsive shock is to be explained in terms of its punishing effect.

The amnesic effects of electroconvulsive shock were studied in the second experiment. Subjects were given subconvulsive shock treatments followed by convulsive shock either 5 seconds or 1 hour later. Twenty-one male rats, similar in age and strain to those used in the first experiment but from a different vendor, were first trained, by the same procedures and with the same apparatus as were used in the first experiment. On the first treatment day all subjects were given a 2-ma shock through the pinnae 5 seconds after they were placed in one of the goal boxes. Ten subjects were then given an electroconvulsive shock 5 seconds later. The other eleven subjects were returned to their home cages after the subconvulsive treatment and reintroduced into the same goal box 1 hour later and given a convulsive shock after a 5-second delay. As in the first experiment, treatments and test trials were given on alternate days.

On the first test trial, six of the ten subjects that received an early convulsive shock chose the nonshock side (see Fig. 2). In the group that received a 1-hour-delayed shock eight of the eleven subjects chose the nonshock side. Further, five of these eight subjects that avoided the shock side did so by going to a nonpreferred goal box, while this was true for only one of the six subjects that avoided the shock side in the early-shocked group. The conclusion that the two groups differed on the first test trial is supported by the latencies. The median first trial latency was 26 seconds for the group that received 1-hour-delayed convulsive shock and only 12.5 seconds for the early-shocked group. This difference is significant at the .05 level (Mann-Whitney test). Further, in the group that received 1-hour-delayed shock, the latencies on the first test trial were higher ($p < .04$, 1-tailed sign test) than those of the last pretraining trial. The first test trial latencies of the group that received early shock were slightly, though not significantly, *lower* than those of the last pretraining trial. This result clearly fails to support the "competing response" interpretation of the effects of electroconvulsive shock. On subsequent trials the latencies of both groups rose markedly and were not significantly different on any day.

The finding that the early-shock treatment did not *prevent* learning with repeated trials is consistent with other studies that used repeated training trials and convulsive-shock treatments (*1*).

These studies, considered together, provide further evidence that electroconvulsive shock affects performance both by producing amnesia and by inducing fear, but that the punishing effect of these shocks is considerably less effective than that of less intensive subconvulsive shocks and is found only with repeated treatments. An understanding of the basis of the punishing effect will require additional research. The data provide no support for the view (*3*) that the amnesic effects of electroconvulsive shock are due to the conditioning of competing responses (*8*).

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**References and Notes**

1. S. E. Glickman, *Psychol. Bull.* **58**, 218 (1961).
2. E. E. Coons and N. E. Miller, *J. Comp. Physiol. Psychol.* **53**, 524 (1960); M. H. Friedman, *ibid.* **48**, 555 (1953).
3. H. E. Adams and D. J. Lewis, *ibid.* **55**, 302 (1962); D. J. Lewis and H. E. Adams, *Science* **141**, 516 (1963).
4. M. C. Madsen and J. L. McGaugh, *J. Comp. Physiol. Psychol.* **54**, 522 (1961).
5. J. T. Heriot and P. D. Coleman, *ibid.* **55**, 1082 (1962); A. Weissmann, *ibid.* **56**, 806 (1963).
6. W. J. Hudspeth, J. L. McGaugh, C. W. Thomson, *ibid.* **57**, 61 (1964).
7. Two subjects were paraplegic casualties: one after two trials and the other after eight trials.
8. Supported by research grants MY-3541 and MH 07015 from the National Institute of Mental Health.

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## Mimicry: Differential Advantage of Color Patterns in the Natural Environment

Abstract. *With a new modification of the release and recapture technique in which day-flying male moths are artificially painted, released, and then lured by their females into traps, it has been possible to obtain differential recapture frequencies in natural areas of the Neotropics.*

During the past 5 years, considerable progress has been made in understanding the evolution of mimicry (*1*) and experiments with caged animals have conclusively demonstrated that substantial protection from predation by birds, toads, and lizards is gained by mimetic butterflies, flies, and beetles (*2*). However, measurements of the selective advantage of mimicry actually occurring under natural conditions have not been attempted. We have now been able to make such measurements by means of a novel adaptation of the method of release and recapture developed by Kettlewell (*3*). An underlying assumption is that differential recapture is the result of differential predation. This seems justified on the basis of Kettlewell's work.

The new technique takes advantage of several biological properties of the saturniid moth, *Hyalophora* (*Callosamia*) *promethea* (Drury), a native of eastern North America. As in all members of this family, the specific sexual attraction of the male to the female is mediated over long distances by a chemical substance known as a pheromone (*4*). Unlike most saturniids, *H.*