Electroconvulsive Shock, Retroactive Amnesia, and the Single-Shock Method

Abstract. *If electroconvulsive shock is given immediately after a learning session, retroactive amnesia for that response occurs. Such results may be due to production of aversive responses or to interference with consolidation of the neural engram, or to both. Aversive responses or competing responses are not adequate explanations for retroactive amnesia. Consolidation theory provides the most plausible explanation. The single-shock method is an appropriate approach for studying the relationships between electroconvulsive shock and retroactive amnesia.*

It has been suggested by Coons and Miller (*1, 2*) and Adams and Lewis (*3, 4*) that electroconvulsive shock (ECS) may not produce retroactive amnesia (the destruction of a recently learned event before it has been consolidated into permanent memory). Miller and Coons (*2*) have offered evidence, using repeated sequences of train-ECS test (sequential-shock technique), that retroactive amnesia may be confounded with aversive effects. However, Pearlman, Sharpless, and Jarvik (*5*) and Madsen and McGaugh (*6*) have recently suggested that such confounding may not occur when just one train-ECS-test sequence (single-shock method) is used. But, from the conclusions of Lewis and Adams (*4*), it would seem that the time at which a single-shock is given, either before or after training, should not affect retention, whereas location, either inside or outside the apparatus, should affect retention.

Thus the purpose of the present study was to evaluate further the appropriateness of the single-shock method for the study of retroactive amnesia. Specifically, an attempt was made to distinguish between retroactive amnesia effects and aversive effects in an experimental situation in which both time and place of ECS were systematically manipulated.

The shock apparatus consisted of a high-voltage transformer (3000 volts a-c) with a Hunter-style electric timer, giving a constant 30 ma current (regulated by a magnetic shunt) for 0.03 sec. The apparatus was capable of producing a full tonic-clonic seizure, with little risk of damage to the animal.

A clear plastic Miller-Mowrer avoidance box was divided into halves by covering one side with black cardboard and the other with white. Coinciding with these areas were two sections of grid floor, with the black side capable of being electrified.

Aversive shock given to the rats through the grid floor of the avoidance box was of the order of 100 volts a-c from a Campbell-type rat shocker with constant current settings. The ECS was administered to the ears through alligator clips covered with cotton moistened in saline.

Thirty albino rats of the Sprague-Dawley strain were divided into five groups of six each. They were all females, between the ages of 85 and 95 days, and were given free access to food and water. In two of the five groups, rats were given ECS 24 hours before training (shock-before-training, SBT). Of these, one group was treated inside the box on the black half (SBT-I), and the other group was treated outside the box on the stone floor of the training room (SBT-O). In two other groups, rats were treated immediately after training (shock-after-training, SAT). Of these, one group was shocked inside the box on the black half (SAT-I), and the other group was treated outside the box on the floor (SAT-O). The control group (C) received no ECS. All animals receiving ECS were allowed to explore their surroundings for 1 minute before ECS was given, and all underwent full tonic-clonic seizures. The two "inside" groups were treated in the black side of the box, so any situational aversive effects of ECS would decrease rather than enhance retroactive amnesia.

All groups were given five training trials in the training box. Each rat was placed in the black side, and a 10-second buzzer was then sounded, which terminated as grid shock was delivered. Rats were freely allowed to cross to the white side of the box as soon as the buzzer sounded, except on the first trial, when they were required to experience the grid shock. After their avoidance response (crossing to the white side), they were gently moved by hand to the black side again. Training took at most 4 minutes to complete. After 24 hours from the end of training, ten retention trials, consisting of retraining trials under the same conditions as the five learning trials, were given without the forced grid shock on the first trial.

The response measure taken was that of error; failure to run when the buzzer sounded resulted in grid shock to the rat. Scores were transformed by the square-root method to meet assumptions of analysis of variance. Table 1 shows error scores for all groups.

Performance of rats on the five learning trials for all groups was compared. Analysis of variance showed no significant differences, indicating that administering ECS prior to training had no significant effect. Analysis of variance on the ten retention trials showed significant differences ($p < .01$), and orthogonal comparisons were made on the ten retention trials which showed no differences between the two groups treated before training (SBT-I as against SBT-O). In addition, there were no significant differences between the groups treated after training (SAT-I as against SAT-O) or between these groups and the controls (SBT-I and SBT-O as against C). However, significant differences were found between groups treated after training and controls (SAT-I and SAT-O as against C, $p < .005$); and between SBT-I, SBT-O, and C as against SAT-I and SAT-O, ($p < .001$). These findings indicate that there were no differences due to location of the rat, either inside or outside of the box, when ECS was administered and that giving it prior to training had no

Table 1. Errors for each group. Abbreviations: SBT, shock before training; SAT, shock after training (electroconvulsive shock); C, control; I, inside of training situation; O, outside of training situation.

Trials	Errors (No.)				
	SBT		C	SAT	
	SBT-I	SBT-O		SAT-I	SAT-O
1–5 Train	21	21	17	18	19
1–5 Test	10	6	7	17	15
6–10 Test	2	1	0	7	5
1–10 Test	12	7	7	24	20

significant effect. However, the results do show that ECS had a disrupting effect if given directly after the five learning trials.

Results of this study support the consolidation hypothesis in showing that retroactive amnesia occurs without aversive effects when shock is not given repetitively and that time of administration affects retroactive amnesia, while location does not. These results are consistent with those of Hudspeth, McGaugh, and Thompson (*7*), who have shown that aversive effects produced by ordinary shock become more intense over trials than aversive effects produced by ECS. They also found that aversive effects produced after repeated ECS sequences were stronger than those produced by the first sequence. The results of the present study suggest that the findings of Lewis and Adams (*4*) were probably due to the aversive effects of repeated ECS sequences. Thus, avoidance and competing response explanations are not adequate to handle retroactive amnesia produced in a single-ECS situation.

We are of the opinion that perhaps the single-shock and the sequential-shock techniques are each appropriate to answer different questions (for example, the relation between ECS and retroactive amnesia on the one hand and the relationship between the shock and aversion on the other). Thus, it is not a matter of which technique or theory is or is not supported; rather it is a matter of which technique is more fruitful or appropriate to answering a particular question.

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References and Notes

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7. W. J. Hudspeth, J. L. McGaugh, C. W. Thompson, *ibid.* **57**, 61 (1964).
8. Paper was presented at the Midwestern Psychological Association, St. Louis, May 1964, by one of us (D.J.L.).

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Statistical Models for Predicting Numbers of Plant Species

In "Species abundance: natural regulation of insular variation" [*Science* **142**, 1575 (1963)], Hamilton, Rubinoff, Barth, and Bush have compared two statistical models for predicting numbers of species from environmental factors. The first is a "linear" model, $y = bx$. The second is a "curvilinear" model $y = bx^z$ where $z \neq 1$. Although they give no exact statement of their test of "goodness of fit," they conclude that model 1 is the superior.

Considering only the relation of species numbers (Y) to area (X_1), much of the question of the form of the relation can be determined by a quick look at a simple scatter diagram. Figure 1 shows a "natural" and Fig. 2 a "logarithmic" plot of the data. Also shown on each plot is the least squares fitted line for a simple regression.

It is readily apparent from Fig. 1 and 2 that the "scatter" about the line of Fig. 2 is more regular than that for Fig. 1. One of the assumptions of the use of goodness-of-fit tests is that the distribution of errors about a fitted line be independent of the value of the independent variable. This condition is not met for model 1.

If errors are to be transformed for comparison, they must be transformed in a manner that is consistent with the regression equation used. Therefore, the sums of the squared deviations

$$\Sigma\ (Y_1 - \overline{Y})^2$$

and

$$\Sigma\ (Y_2 - \overline{Y})^2$$

are not directly comparable. Perhaps one might compare the two errors by converting the error in log units at the mean value of the relation of Fig. 2. This, then, would be grossly comparable with the standard error of estimate from Fig. 1. For a mean of 119.3 and a standard error of 93.7 species, the range of the confidence interval at the mean is from 26 to 213 species for model 1. The comparable range for model 2, with a standard error of 0.331 log units, is 56–255. The exclusion of one extreme value, Albemarle, changes the equation for model 1 from

$$y = 95.4 + .12X \text{ (SE 95)}$$

to

$$y = 70.3 + .48X \text{ (SE 86)}.$$

The comparable change for model 2 is from

$$y = 28.6\ X^{0.331} \text{ (SE 0.319)}$$

to

$$y = 28.2\ X^{0.339} \text{ (SE 0.332)}.$$

Figure 1 also gives a good visual picture of why "Model 1 predicts floral richness for larger islands more accurately than it does for smaller islands." This is a result of the least squares fitting itself. The few larger islands receive much more weight than all the data for smaller islands. The two figures give an indication of why X_1 is significant for model 2 but not for model 1.

The expected relation of errors to the "true" values may give some perspective to the problem of choosing a model. Assume an island were observed to have 10 species and a "satisfactory guess" would be in the range of 5 to 15 species, or ± 5 species. If a second island were observed to have 1000 species, would a "satisfactory guess" need to fall between 995 and 1005 species? This is the requirement of model 1. Probably, the proportional errors of model 2 would be preferable. If a guess of 6 to 17 is good enough for 10, then a guess of 600 to 1700

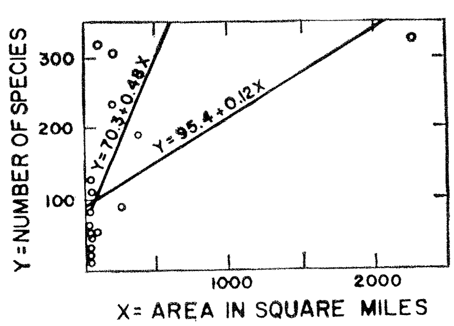

Fig. 1. Relation of species number to area, plotted to natural scales.

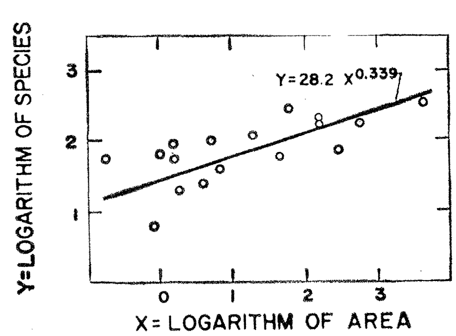

Fig. 2. Relation of species number to area, plotted to logarithmic scales.