Retroactive amnesia from electroconvulsive shock: Consolidation disruption or interference?¹

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Abstract

The amnesic effect of electroconvulsive shock has been explained in terms of consolidation theory and in terms of interference hypotheses. Crucial evidence is not yet available for choosing between these alternative explanations, and it appears that many variables (including the nature of the response measure used and the number of seizures administered to the S) influence the results of studies in the area. The present study is a modified replication of an earlier experiment, and offers evidence in favor of an interference interpretation of the effects of electroconvulsive shock on learned responses.

Problem

Electroconvulsive shock (ECS) administered at some time interval after an animal has learned to perform a particular task has the capability of reducing performance on that task in subsequent trials. Several hypotheses have been advanced to explain this phenomenon. One hypothesis is that the shock disrupts neural activity necessary for the formation or consolidation of a memory trace (Duncan, 1949). Another view suggests that ECS is aversive and that the animal learns to avoid making responses which are followed by ECS in much the same manner that other aversive stimuli (e.g., peripheral shock) produce response elimination (Coons & Miller, 1960). A third hypothesis is that ECS elicits competing responses which interfere with the acquisition or retention of other responses. It has been suggested that such competing responses may be related to the conditioned crouching-freezing pattern of behavior (Adams & Lewis, 1962; Lewis & Adams, 1963). However, the conditioned "crouch-freeze" is only one of many competing responses which may be elicited by ECS.

Many studies have been undertaken for the purpose of evaluating these hypotheses and selecting between them, but no clearly definitive study has yet been performed. It has been suggested (Leonard & Zavala, 1964) that support for the consolidation hypothesis comes primarily from those studies which utilize a single ECS, while support for the interference hypotheses is obtained when multiple seizures are evoked. It has also been suggested (Gerbrandt & Thompson, 1964) that an important variable in these studies is the nature of the response measure which is used, with passive avoidance tasks tending to support a consolidation interpretation and active avoidance tasks supporting an interference hypothesis.

In a recent experiment, McGaugh & Madsen (1964)

trained water-deprived rats to run a T-maze for water reward. On the tenth day, the Ss were placed in the goal box and were given a subconvulsive shock through the pinnae. Either 5 sec. or 1 hr. later, the rats received ECS in the goal box. On the first post-ECS trial, the Ss which had received early ECS exhibited slightly lower response latencies than they did on the last training trial. The authors interpret their data as being contrary to the competing response hypothesis.

According to our view of the competing response interpretation, there is no reason to expect a longer test trial latency since the Ss were given ECS in the goal box on the day after the last training trial. In addition, the test trial data were obtained by placing the rats in the start box which had never been associated with ECS.

Method

The present experiment replicated the McGaugh and Madsen study with two modifications: ECS was administered in either the goal box or the start box, and both subconvulsive shock and ECS immediately followed a training trial. Thirty-six water-deprived Dublin Sprague-Dawley male rats (90 to 105 days old) were given eight days of preliminary training in an alley T-maze, the goal boxes of which differed in brightness, shape, and texture. The left goal box was white, circular, and lined with window screening. The right goal box was black, square, and lined with hardware cloth. The starting alley was grey. Guillotine doors at the start box and on either side of the choice point prevented retracing. On days 1 and 2, the Ss were placed in the goal box and were allowed to drink for 10 min. in each box. On days 3 through 6 the Ss were placed in the start box and were allowed to run to the goal box for a 30 sec. drinking period, for one trial each day. On days 7 and 8 the Ss ran four trials per day with an intertrial interval of approximately 30 min. Equal exposure to the two goal boxes was insured by forcing responses on half the trials. On day 9, each rat was given one free-choice trial, allowed to drink for 30 sec., and then given a subconvulsive shock of 2 ma by means of alligator clips attached to the pinnae. The subconvulsive shock was administered in the preferred goal box. ECS was then administered either 10 sec. or 1 hr. later. Half of each group received ECS in the goal box and half in the start box. On day 10 one trial was given in the maze. Response latency (time between the opening of the start box door and the animal's exit from the start box) and running time (time between exit from the start box and entry into the goal box) were recorded.

Results

A mixed model analysis of variance indicated that the pre- and post-treatment latencies were significantly different ($p < .01$; $F = 15.50$, $df = 32$). This mean difference was strikingly large—0.92 sec. for the pre-treatment trial versus 5.97 sec. for the post-treatment trial. The location of the ECS administration was not significant ($p < .20$; $F = 2.09$, $df = 1,32$) and the elapsed time between subconvulsive shock and ECS was not significant ($F = 1.09$, $df = 1,32$). None of the interactions between these variables was significant.

The running time data were subjected to a similar analysis. Pre- and post-treatment running times were significantly different ($p < .01$; $F = 17.62$, $df = 1,32$), with the pre-treatment mean of 9.4 sec. comparing to the post-treatment mean of 44.9 sec. In terms of the running time response measure, the elapsed time between subconvulsive shock and ECS approached, but did not reach, significance ($p < .10$; $F = 3.66$, $df = 1,32$). The mean running time for the 10 sec. ECS group was 34.6 sec., while the group which received ECS 1 hr. later exhibited a mean running time of 19.7 sec. No significant difference in running time was found between the Ss receiving ECS in the start box and those receiving it in the goal box. However, 13 of the 18 animals given ECS 10 sec. after subconvulsive shock chose the goal box in which shock was not received, while only 6 of the 18 animals receiving delayed ECS chose the goal box in which shock was not received. These results suggest that the animals avoid the box in which both subconvulsive shock and ECS are obtained, a finding not in accord with the consolidation hypothesis.

Discussion

The results obtained here are in conflict with those obtained by McGaugh and Madsen. The important procedural difference seems to lie in the fact that our animals received subconvulsive shock and ECS immediately after a trial, while McGaugh and Madsen did not use a maze trial on the treatment day. That

such a procedural variable is important is supported by the findings of Misanin & Smith (1964), who noted a significant impairment in acquisition and retention of an avoidance response if ECS followed a running response but not if the ECS was administered when the animal was not making a running response. Thus, it appears that the distinction between active and passive avoidance tasks may be an important one in resolving the conflicting interpretations of studies on ECS and memory. Consolidation hypotheses predict an amnesic effect of ECS regardless of the type of response measure used, since ECS is alleged to act directly on neural processes involved in engram formation or consolidation. Interference hypotheses, on the other hand, emphasize the importance of the response measure. Our data thus support an interference explanation of the effects of ECS on memory.

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Note

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