Recovery from ECS-produced amnesia following a reminder

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Rats were trained to drink from a water tube and were then shocked at the tube. ECS was delivered 5 sec after escape into another chamber. Controls received only training to drink, and ECS. All Ss were then tested one day later for readiness to drink, and there was little tendency to avoid in either condition. Half the FS-ECS and all the ECS-only animals were then given a mild reminder shock, and all animals were retested. Footshock-ECS reminded animals showed a greatly increased tendency to avoid the drinking box, while non-reminded FS-ECS and ECS-only controls showed very little avoidance.

The notion that learning is stored in a relatively permanent memory only if there is a period of neural consolidation extending beyond active practice has its most convincing support from studies of retrograde amnesia (RA) for one trial passive avoidance learning. In these studies punishing footshock is followed by one of a variety of agents, most notably electroconvulsive shock (ECS), which produce rapid unconsciousness. Animals administered ECS immediately following the aversive learning trial show little or no sign of the avoidance typical of non-ECS controls when returned to the footshock situation after a day or two (e.g., Quartermain, Paolino, & Miller, 1965).

The problem to which this report is addressed is the nearly exclusive reliance in these studies on a simple test trial to determine the degree of memory for the punishing shock. It is well known from studies of human and animal memory that even when such simple tests give little evidence of memory, other tests, such as recognition or relearning, often reveal considerable memory. If the complete amnesia found when ECS has followed learning by a few sec is the result of lack of memory consolidation, then there should be no memory to be found, by whatever means. Increasing the variety of probes for evidence of memory in this situation will probably reveal a good deal about the plausibility of the consolidation notion, and about the nature of RA.

In the study reported here the retention test employed was essentially a relearning one. Rats rendered amnesic by administration of ECS within a few sec of punishing footshock were given a mild "reminder" shock 40 min before subsequent testing. (The reminder shock was of a magnitude sufficient to produce little avoidance behavior itself.) Three conditions were employed; the two of primary concern were: punishing footshock followed within 5-10 sec by ECS (FS-ECS), and ECS-only. Neither of these conditions should produce much avoidance behavior on a simple test trial. Twenty-four h after ECS the animals were first tested for retention, then given the small reminder shock and retested. As a control for the effects of retesting (Zinkin & Miller, 1967) a FS-ECS condition without a reminder was added.

Method

Twenty-four 90-110 day old male Holtzman rats, eight in each condition, were put on a 23 h water deprivation schedule for at least a week before they were trained to drink in a gray 17 x 6 x 13 in. box with a grid floor. A 2 x 2 in. hinged plate on an end wall covered a water tube. The rats learned to press and hold this plate so that the tube was accessible through a hole in the plate. All animals received six 180 sec drinking session, two daily for three days, prior to the avoidance training day. On the last pretraining day the animals were also adapted to wearing padded alligator earclips for a few sec in the box, and were given experience entering the drink-shock box from a Plexiglas cage which was identical to the animals' home cages. Entry into the drink-shock box was through a door in the end-wall opposite the water tube and cover plate.

On the training day, saline-soaked earclips were applied and each animal was put in the drink-shock box and allowed to drink for 5 sec. At this point, animals in the footshock conditions received intermittent 1.6 mA, .5 sec shocks delivered to the grid, water tube and cover plate through a shock scrambler. At the time the first shock was delivered, the door in the opposite wall was opened, allowing escape to a 7 x 10 x 8 in. black box, in which ECS was administered. Footshocks were delivered every 2 sec until the animal escaped. Five sec after escape into the black box, ECS (75 mA, .2 sec duration from a high voltage source) was delivered. Full tonic-clonic seizures were produced in all animals, with none of the animals lost through injury. The mean number of footshocks received before escape was 1.88 (range from 1 to 3). Thus, the elapsed time from the first footshock to convulsion varied from approximately 6 to 11 sec.

No-footshock animals (ECS-only) were manually removed from the waterspout after 5 sec of drinking and pushed through the door into the black box, where ECS was delivered 5 sec later. Actually, only three or four animals in each condition would drink with earclips applied. For the animals not drinking within 10 sec, footshock was delivered or the control was pushed into the black box. Retention test performance was not influenced by whether the animal drank or not during the training session.

Twenty-four h after ECS, the animal was placed in the clear Plexiglas entry cage now attached to the

Table 1 Mean latencies to enter and to drink, pre- and post-reminder

Condition	Pre-reminder		Post-reminder	
	Enter	Drink	Enter	Drink
FS-ECS, reminder	8.1	19.3	330.8	366.5
ECS-only, reminder	3.5	12.6	31.3	68.6
FS-ECS, no reminder	7.1	18.1	20.9	24.4

drink-shock box, for an initial pre-reminder "entrance" test (a passive avoidance test). At the end of the 180 sec test a reminder footshock (.2 mA, .5 sec) was administered while the animal was drinking. Escape was not allowed; the animal was manually removed after 5 sec. Forty min later, there was a post-reminder entrance test. Fifteen min following conclusion of that test, the animal was placed directly in the drink-shock box, facing the water-spout, for a 180 sec "exit" test (an active avoidance test).

Results

Table 1 shows the mean latencies to enter and to drink before and after the reminder shock. All 24 animals entered and drank during the pre-reminder entrance test, confirming RA findings of previous studies. Since all animals did not enter and drink during the post-reminder entrance test, the post-reminder latencies were based on the total 360 sec of the entrance and exit tests. (Entrance latencies were always based on active entrance into the box.) After the reminder four of the eight FS-ECS animals did not enter the treatment box and six did not drink during the two post-reminder tests (arbitrary latencies of 400 sec were assigned in these cases), while all 16 animals in the other two conditions entered and 15 drank during the post-reminder entrance test, and the remaining ECS animal drank during the following exit test.

A 3 by 2 analysis of variance of condition (between Ss) by pre- and post-reminder (within Ss) on reciprocal transformations of the entrance latencies yielded a significant pre vs post main effect ($p < .01$) and a significant interaction effect ($p < .05$). Comparisons of individual cell means, using error estimates from the larger analysis, confirmed that the nature of the interaction was that which is obvious in Table 1: the latencies in the FS-ECS condition following the reminder were significantly larger than those in any other condition. The pre-post differences in the ECS-only and FS-ECS, no-reminder conditions had ps between .05 and .10. Of course, the small n did not allow a very sensitive test of what may be small effects of the reminder alone (ECS-only) or retesting (FS-ECS, no reminder).

A similar analysis on the drink latencies yielded essentially the same results, except that the effect of the reminder in the ECS-only condition was significant at the .05 level.

The pattern of results is quite clear. Before the reminder shock, FS-ECS animals and -ECS animals were very similar in their readiness to enter the treatment box and approach the waterspout. However, the small reminder shock clearly differentiated animals given and not given original punishing shocks. Animals which had been amnesic for the punishing shock showed very persistent avoidance, both active on the exit test and passive on the entrance test. The latency to exit for FS-ECS reminded animals was 3.6 sec. The -ECS reminded animals and the FS-ECS non-reminded animals also exited fairly rapidly ($\bar{X}s = 5.1$ and 6.4 sec, respectively) but they reentered (and drank) rapidly ($\bar{X}$ reentry latencies of 4.3 and 9.4 sec respectively). In contrast four of the eight FS-ECS reminded animals did not reenter the drink-shock box, and the mean reentry latency of the other four was 101 sec. There was obviously a well-discriminated avoidance of the drink-shock box in the FS-ECS reminded animals.

Since the reminder shock preceded the first "post" test by 40 min, during which the animals were in their home cages, it seems unlikely that the subsequent avoidance reflected any transitory excitability. Rather, the avoidance undoubtedly reflected the release, by the reminder, of a memory laid down by the experience of the original punishing shocks.

Discussion

The results of this study, taken in conjunction with Zinkin & Miller's (1967) demonstration of recovery from ECS-produced amnesia over time and repeated testing, strongly suggest that ECS inhibits or suppresses a fully formed memory. The reminder effect appears to fit the general class of phenomena in which extinction and interference effects on retention are precipitously dissipated by relearning. We do not see how the strong avoidance exhibited in this study by FS-ECS animals following a reminder can possibly be consonant with an interpretation that their pre-reminder amnesia was due to any failure of the memory to form or consolidate.

References

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Note

1. This research was supported by Grant MH11284 from the National Institutes of Health.