Reports

Retrograde Amnesia from Conditioned Competing Responses

Abstract. *If electroconvulsive shock is given immediately after a learning trial, retrograde amnesia for that response occurs. The usual interpretation of such amnesia states that a neural engram, after a learning trial, requires a certain amount of time to consolidate, and electroconvulsive shock interferes with this consolidation, producing amnesia. Four studies are summarized which indicate that convulsive shock serves as an unconditioned stimulus producing a convulsive response, that takes precedence over other behavior, and part of which becomes conditioned to stimuli in the learning situation. The convulsive response competes with, and replaces, the previous response, resulting in the appearance of amnesia.*

The familiar retrograde amnesia produced by electroconvulsive shock (ECS) is most commonly interpreted as a result of the failure of a neural trace or engram to consolidate (*1*). According to this interpretation, a learning trial produces an engram which requires a period of time to become fixed in the nervous system. If convulsive shock is administered during this time, a physiological "storm" is created which disrupts the consolidation process and forgetting, or retrograde amnesia, is the result.

In two recent studies, Adams and Lewis (*2*, *3*) attacked this interpretation and presented a counter one based on the principles of classical conditioning. They argued that convulsive shock serves as an unconditioned stimulus which elicits a prepotent unconditioned response, the convulsion. This convulsion, or part of it, becomes conditioned to stimuli (or their traces) present at the time of convulsion, and competes with (replaces) any other learned responses to the conditioning stimulus. Thus, the retrograde amnesic effect is due to the replacement of one response with another.

To test their interpretation, Adams and Lewis (*2*) gave their albino rat subjects training trials in a two-compartment shuttle box, the first compartment of which contained a grid floor through which mild shock to the feet could be delivered. The subject was placed in the first compartment, the gate of the second compartment was opened, and the conditioning stimulus, a small flickering light in the first compartment, came on. Ten seconds after the light came on, the grid floor of the first compartment was electrified. If the animal left the first compartment within ten seconds of the onset of light, it did not receive the grid shock. Such a departure was counted as a successful avoidance response.

One group of animals was given convulsive shock in the first compartment of the shuttle box 3 days before they were to learn the avoidance response. The results very clearly showed that these animals had great difficulty learning the postconvulsive avoidance response although those that did not experience a convulsion learned with no difficulty. No consolidating engram could be involved here because the learning of the avoidance response occurred long after the termination of the convulsive shock. A form of "prograde amnesia" was produced, the explanation of which is derived from the principles of classical conditioning. The convulsion, with convulsive shock serving as the unconditioned stimulus, occurred in the first compartment, and at least part of the convulsion became conditioned to the stimuli of that compartment so that the animals learned to crouch and huddle when placed there again. The crouching and huddling interfered with the learning of the avoidance response, yielding prograde amnesia.

In a second experiment, Adams and Lewis (*3*) varied the place in which the convulsive shock was given. If part of a convulsion can be conditioned, then the stimulus situation in which the convulsion occurs must be important. Animals were given learning trials in the shuttle box, followed by convulsive shock.

For one group the convulsive shock was given in the first compartment, and for another it was given on an open white table where the properties of the stimulus were very different from the black confinement of the first compartment. A great deal more retrograde amnesia was produced in animals given convulsive shock in the first compartment than in those given it on the open white table. These results indicate that, whatever the consequences of convulsive shock, they are, to a considerable extent, "stimulus bound." Again, a neural-consolidation interpretation is not appropriate because convulsive shock was given at the same time interval after the avoidance response for both groups, and the same amount of interference with the engram should have occurred in both groups. Clearly, this was not the case.

If convulsive shock is an unconditioned stimulus producing a response which becomes conditioned to a conditioning stimulus, then it should be possible to extinguish that response. In a third experiment (*3*), two groups of animals were given a series of acquisition trials in the shuttle box with each trial being followed immediately by a convulsion. Then the subjects of one group were placed, two at a time, in the closed first compartment. They were left there for 5 minutes at a time on five successive days. Although no formal record was kept of their movements, it was noticeable that they became more and more active as this extinction experience continued. The other group remained in its living quarters during this extinction period. Then the subjects of both groups were returned, one at a time, to the shuttle box to relearn the avoidance response. The group that had received the extinction experience acquired the avoidance response quite readily, whereas the other group showed very little relearning.

A fourth, and not previously reported, experiment also makes clear that the retrograde amnesia produced by convulsion is due largely to competing responses, and very little, if at all, to interference with a consolidating neural engram.

After the subjects were placed in the first compartment of a shuttle box, the gate to the second compartment was opened and simultaneously a light in the first compartment began to flicker. Ten seconds later the grid floor of the first compartment was electrified, and immediately after the animal jumped into the second compartment the gate was closed behind him. Three trials a day were given each subject in quick succession. Convulsive shock was administered by alligator clips attached to the ears after the third trial. This treatment continued for 4 days, resulting in a total of 12 avoidance trials and four convulsions. Approximately 5 minutes lapsed between the onset of the first trial and the administration of ECS on each day. On the 5th day each subject was given 15 successive avoidance trials without convulsive shock. These were essentially relearning trials, and the response measure was the number of successful avoidances on these relearning trials.

The critical aspect of the experiment was the place at which the subjects were convulsed. The subjects of one group were removed from the second compartment, alligator clips were attached to their ears, and they were put back in the first compartment, where they were convulsed. A second group was treated in an identical fashion except that these subjects were returned to the second compartment for convulsion. The third group was convulsed on an open white table.

In all cases the convulsive shock was a 35-ma current administered for 0.3 second. It produced a tonic-clonic convulsion which lasted from 5 to 15 seconds. Immediately after the convulsion began the subjects were returned to their cages where they recovered.

Because the properties of the electric current were uniform for all subjects and because the convulsion followed the learned response by the same time interval, the three groups should not have differed, according to a consolidation theory. The competing-response theory, however, predicts considerably different consequences.

When convulsive shock is given in the first compartment it should result in the strongest competition for the avoidance response, and therefore the greatest decrement for this response; subjects will crouch and huddle instead of jump. Convulsion in the second compartment should have little effect upon the avoidance response because the conditioned crouching and huddling will not occur until avoidance response is over. Convulsive shock on the open platform should also have little effect on the avoidance response because it occurs in the situation most dissimilar to that of the first compartment. Because the second compartment is like the first in size and shape, although different in color, more competition will occur when convulsive shock is given there rather than on the open table.

The total number of avoidance responses during the fifteen relearning trials for the group receiving convulsive shock in the first compartment was 61; in the second compartment, 84; and on the open white table, 98. A Kruskal-Wallis one-way analysis of variance yielded an H of 41.2 which was significant, $p < .001$. Mann-Whitney U-tests between the first and second compartment groups, between the first and third compartment groups, and between the second group and the white table group were all significant, $p < .001$.

These data add confirmation to the competing-response interpretations of retrograde amnesia, and the consolidation hypothesis, which has most frequently been applied to phenomena of this sort, does not seem to be adequate. The consolidation hypothesis was first advanced by Muller and Pilzecker (*4*) to explain the forgetting of verbal materials. The learning of a first list of verbal materials, they reasoned, produced neural engrams which consolidated as time elapsed.

If another list was given soon after the first, the consolidation of the engrams from the first list would be interrupted and forgetting of the first list would result. Most investigators of verbal learning (*5*), however, now prefer a competing response interpretation of forgetting rather than a consolidation theory. The consolidation theory remains widely held by many researchers with a physiological orientation and Glickman (*6*) ably marshals evidence to support this theory.

Coons and Miller (*7*) have explained the phenomena of retrograde amnesia as a result of fear-produced avoidance. The data of the fourth experiment reported here do not conform to this interpretation, for the animals would have had to avoid the compartment in which they were convulsed. Instead they remained in that compartment (*8*).

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References and Notes

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10 June 1963

Artificial Feeding of Neonatal Rats

Abstract. *Newborn rats, fed either cow's milk or rat's milk by tube, developed a "bloat" and the time required for emptying the stomach increased. When these animals were allowed to suckle on nonlactating foster mothers, no evidence of this syndrome was observed. Based on these observations, a technique was developed for the artificial feeding of newborn rats. When the diet was rat's milk, growth equivalent to that of animals fed solely by lactating females was obtained. A diet of cow's milk did not support adequate growth.*

There has been increasing interest in recent years in the influence of nutrition on the growth and development of the infant animal. With the exception of a limited number of studies in farm animals (*1*), most of these investigations have been performed with infant animals suckling on lactating females (*2*). This has been particularly true of the work with the rat, an animal whose feeding behavior is relatively complex (*3*). A notable exception to these studies has been that of Pleasants (*4*) with gnotobiotic animals. However, even in this case, the growth obtained with tube-feeding techniques was significantly inferior to that obtained with animals fed on lactating females.

During the course of an investigation of the nutrient needs of infant rats, it became apparent that a technique for feeding semipurified diets would be required. Using a modified intubation technique similar to that reported by Pleasants (*4*), we were unable to obtain reasonable growth rates and survival. In general, infant rats fed by intubation developed a syndrome which included an increase in the time required for the stomach to empty and a "bloat" characterized by an accumulation of gas in the stomach and small intestine. Death