Some properties of ECS-induced amnesia for a long-term habit

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Two experiments investigated the phenomenon of ECS-induced amnesia for a long-term habit acquired in a K maze for food reward. In Experiment I, rats acquired a position habit in the K maze, and half of the subjects were extinguished to handling and startbox cues for 7 days. On the 7th day, half of the extinction subjects and half of the subjects not given extinction were individually placed in the startbox of the K maze and given ECS. The remaining subjects were placed in the startbox and given sham ECS. Half of the subjects in each of the four resulting groups were tested at 24 h, and the remainder were tested at 96 h. The results of the 24-h test supported a previous finding that ECS subjects not given prior extinction to handling and startbox cues showed amnesia. However, this amnesia was transient, as indicated by memory recovery in subjects tested at 96 h. Experiment II failed to provide any evidence that ECS, when preceded by footshock, induced amnesia for the K maze position habit under conditions of food reward. These results suggest that the nature of the stimulus preceding ECS is critical to the production of amnesia and that the nature of the amnesia effected under these conditions may result from a dissociation of learning.

Several instances of electroconvulsive shock (ECS) induced amnesia for long-term habits have been reported during the last few years. This effect has been obtained in a variety of tasks and at several extended training to ECS intervals ranging from 24 h to days. For example, Misanin, Miller, and Lewis (1968) reported that ECS, when preceded with training cues, effected an amnesia for fear conditioning established 24 h previously, and this result was subsequently replicated by DeVietti and Holliday (1972). Mayse and DeVietti (1971) found that ECS, preceded by footshock, given 3 days following acquisition of a position habit in a water T maze resulted in amnesia as determined by reversal training 24 h later. Several investigators have shown ECS-induced amnesia for long-term habits following training in a Kreschevsky maze. Meyer and his associates (Howard & Meyer, 1971; Robbins & Meyer, 1970) reported that ECS administered following acquisition of a discrimination in the Kreschevsky maze (K maze), resulted in amnesia for a discrimination acquired earlier in the maze if, and only if, that previous habit was acquired under the same motivational conditions as the habit which preceded ECS. Also, Lewis and his colleagues (Lewis & Bregman, 1973; Lewis, Bregman, & Mahan, 1972) found that animals trained to run a specific position sequence in the K maze showed amnesia for the habit when given ECS 7 days after acquisition if, and only if, maze cues preceded the ECS.

These demonstrations of amnesia resulting from ECS are almost certainly due to an action of ECS on memory processes other than memory storage since the amnesic treatment was administered at very long intervals subsequent to training and thus presumably long after consolidation.

One interpretation of these data has been that ECS results in a memory retrieval failure that may be but a special case of the amnesia induced when ECS closely follows a training trial (Lewis & Bregman, 1973). On the other hand, data from our laboratory (DeVietti & Larson, 1971; Mayse & DeVietti, 1971) have led us to believe that ECS-induced amnesia for long-term habits may be due to a state dependency phenomenon. Thompson and Grossman (1972) have also arrived at a similar conclusion.

DeVietti and Larson (1971) fear conditioned rats by pairing a tone with footshock and, 24 h later, gave noncontingent footshock and ECS to some subjects in a different apparatus. These subjects, compared to controls given just noncontingent footshock, showed amnesia of fear conditioning 24 h later and memory recovery at 96 h. Memory was also evident in noncontingent footshock-ECS subjects tested only in the 96-h test, indicating that repeated testing, itself, did not produce memory recovery. DeVietti and Larson suggested that these data were consistent with the notion that footshock and ECS interacted to produce a dissociation of learning, e.g., that footshock and ECS resulted in a modified brain state at 24 h which had dissipated at 96 h. To test this notion, DeVietti and Larson conducted a second experiment in which rats were fear conditioned and given noncontingent

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footshock and ECS as in their first experiment. Some of these subjects, as well as some of the controls given just noncontingent footshock, were given three extinction trials the following day (24 h after footshock and ECS). Other subjects in both groups were not given extinction trials. All subjects were tested for memory of fear conditioning 96 h after noncontingent footshock or noncontingent footshock and ECS. The results showed that subjects given noncontingent footshock and extinction experience showed little retention of fear conditioning relative to subjects not given the extinction experience. On the other hand, both groups of subjects given noncontingent footshock and ECS, regardless of whether they also were given the extinction experience or not, showed strong retention of fear conditioning. This result is clearly consistent with the notion that footshock and ECS result in a dissociation at 24 h that has dissipated at 96 h.

Mayse and DeVietti (1971) obtained data in a water T maze which also support the notion that footshock and ECS can result in a dissociation of learning. Subjects learned a position habit in the maze and were tested for retention 72 h after training by requiring that they learn the reverse position habit. Thus retention was indexed by negative transfer. Groups were differentiated on the basis of the treatment given 24 h prior to training and/or testing. Subjects given footshock and ECS prior to both training and testing, as well as subjects receiving no treatment prior to training and testing, showed excellent retention of training as indicated by a large degree of negative transfer. On the other hand, subjects trained 24 h after footshock and ECS and tested 96 h later without preceding footshock-ECS showed poor retention of training as did subjects trained without preceding footshock-ECS but tested 24 h following footshock-ECS. It is important to note that ECS alone did not effect a dissociation either in this experiment or in the DeVietti-Larson experiment. Thus it appears that some event, e.g., footshock, must precede ECS to effect amnesia for long-term habits. The data of Lewis and his colleagues (Lewis & Bregman, 1973; Lewis et al., 1972) also suggest that ECS alone is not sufficient to effect amnesia for long-term habits.

The present experiments were designed to replicate the essential features of Lewis et al. (1972) to determine if amnesia induced by the interaction of maze cues and ECS, administered 7 days following acquisition of a complex position habit in the K maze, would be obtained at 24 h followed by memory recovery at 96 h as predicted by the state dependency hypothesis. We also explored the possibility that footshock preceding ECS would be a sufficient condition to effect amnesia under conditions of the K maze task.

EXPERIMENT I

This experiment replicated the essential features of the second experiment reported by Lewis et al. (1972)

and, in addition to testing subjects 24 h after ECS or sham ECS, other subjects were tested at 96 h to test for memory recovery should amnesia be obtained in ECS subjects at 24 h.

Method

Subjects and apparatus. Subjects were 56 naive male Long-Evans rats from the Central Washington State College psychology animal colony. All subjects were between 90 and 120 days of age at the beginning of training. The apparatus consisted of a K maze (Krechevsky, 1932), a Dashiell maze, and an ECS shock source.

The K maze consisted of a startbox (16.5 x 23.5 cm) followed by four choice boxes (23.5 x 40 cm) in which the subjects could make either a left or a right turn and a goalbox (17.5 x 23.5 cm). The maze was constructed of plywood sides and floor with a clear Plexiglas top. Each choice box contained a right and a left pathway, either one of which could be blocked by the placement of a removable barrier. A black muslin curtain was fixed to both the left and the right pathways, thereby obscuring the subjects' vision of the removable barrier. Between each section of the maze was a guillotine door which was used to prevent retracing. The entire apparatus, except for the Plexiglas cover, was painted flat black. The maze was lighted by eight 15-W bulbs, one of which was located behind each curtain but in front of the removable barrier. This was the only illumination provided in the windowless experimental room. The Dashiell maze, 104 cm square with nine inserts (20 cm square), was used to provide exploration experience and familiarize the subjects with food reward. The transpinnate ECS was administered through alligator clips with the teeth flattened outward to reduce the pain and extend the electrode surface. These clips were wired to the shock source which delivered a 92-mA shock for a duration of 200 msec (60 Hz, 1,840 V rms).

Procedure. Subjects were separated from the brood colony and individually caged in completely automated, self-cleaning racks. The temperature was held at 72° and the humidity at 50%. Lighting in the experimental colony room was maintained on a 12-h-light/dark cycle. All subjects were given water ad lib throughout the experimental procedure. Food was withheld for 2 days following recaging in the experimental colony. On Days 3 and 4, pairs of animals were placed in the Dashiell maze for 3 h where Noyes pellets had been scattered about the floor. During this 2-day period, the animals' only access to food was in the Dashiell maze. Subjects then remained in their home cages for 2 days and were given 15 g of Lab Chow on the 2nd day. Following this, subjects were individually placed in the goalbox of the K maze and remained there until each had consumed the eight Noyes pellets which had been placed in the foodcup. Then subjects were placed in the choice box immediately preceding the goalbox and allowed to take either the left or the right path to re-enter the goalbox, where they were again allowed eight Noyes pellets. On the following day, the subjects were individually placed in the startbox and allowed to proceed through the maze with no barriers in place, thereby allowing the subjects to traverse the maze without regard to pattern of choice. All subjects were given 10 such trips through the unblocked maze, 3 on the 1st day, 3 on the 2nd, and 4 on the 3rd day. Throughout this phase and the remainder of the experiment, subjects were given 15 g of Lab Chow in their home cages following the day's maze work.

The maze pattern training was started on the day following the 10th unblocked trip through the K maze. The barriers were placed in the choice boxes so as to require half of the subjects to learn a RLLR pattern and the other half to learn a LRLR pattern. Ten trials were given on each training day, and the training was continued until the subjects made 11 out of 12 choices correctly. An error was scored whenever a subject displaced the muslin curtain of the incorrect choice path.

Table 1
Mean Errors ($\pm$ One Standard Error)

Group	Retention Test	
	24 H	96 H
ECS		
H-SB Ext	1.43 ($\pm .48$)	2.00 ($\pm .53$)
No H-SB Ext	3.57 ($\pm .92$)	1.14 ($\pm .40$)
No ECS		
H-SB Ext	.43 ($\pm .20$)	2.71 ($\pm .61$)
No H-SB Ext	1.14 ($\pm .40$)	1.43 ($\pm .57$)

Note—Each of the eight conditions contained seven subjects.

Once the subjects had reached the criterion, they were returned to their home cages for 7 days. During this 7-day retention period, half of the subjects were individually removed from their home cages, transported to the experimental room in a carrying cage, and then placed in the startbox of the K maze. The guillotine door between the startbox and the first choice box was lowered, thereby preventing the subject from leaving the startbox. The subject remained in the startbox until it oriented toward the guillotine door or until 1 min had elapsed. The subject was then removed from the startbox and returned to the carrying cage for 15 sec. This procedure for the extinction of handling and startbox cues (Lewis et al., 1972) was repeated five times on each of the 7 retention days for each subject in this group.

On the 7th retention day, following the fourth startbox placement, $\frac{1}{2}$ of these animals were given an ECS in the startbox and $\frac{1}{2}$ were given a sham ECS (i.e., ear clips were attached but no current was passed).

The 28 remaining subjects were retained in their individual home cages throughout the 7-day retention period. During this period, these subjects were not handled except that on the 7th day they were individually removed from the home cages, transported to the experimental room, ear clipped, and placed in the startbox of the K maze. Half of these subjects were given ECS and half were given a sham ECS.

Following the ECS or sham ECS, all subjects were returned to their home cages. Half of the subjects in each of the treatment groups were tested for retention of the maze habit 24 h after ECS or sham ECS, and the remaining $\frac{1}{2}$ were tested at 96 h. Testing consisted of retraining the subjects to the same 11/12 correct choice criterion employed in the initial training. The number of errors to reach criterion in retraining served as data for analysis.

Results

Table 1 shows the mean errors required by each group to relearn the maze. The error scores were analyzed with a 2 by 2 by 2 analysis of variance with the extinction procedure (present or absent), ECS (present or absent), and time of test (24 or 96 h) as main effects. This analysis revealed the only reliable effects to be in the form of interactions between ECS and the test intervals ($F = 8.08$, $df = 1/48$, $p < .01$) and between the extinction procedure and the test intervals ($F = 10.30$, $df = 1/48$, $p < .01$). In the former case, the analysis of the simple main effects showed that subjects given ECS made more errors than their controls in the 24-h test. This same comparison of the 96-h test performance was not significant. Another effect appearing in this interaction was that subjects not given ECS made more errors at 96 h than at 24 h, whereas a nonsignificant

trend in the opposite direction appeared in subjects given ECS. The breakdown of the interaction between the extinction procedure and the test intervals indicated that subjects given extinction to startbox cues made fewer errors in the 24-h test, compared to subjects not given extinction, whereas a reverse, nonsignificant, trend was apparent in the 96-h test. Also, subjects given extinction made more errors at 96 h relative to 24 h while the opposite trend occurred in those subjects not given extinction.

Specific comparisons among the individual groups were performed with *t* tests using the error term from the analysis of variance in the estimate of the standard error. The results of these comparisons among groups tested at 24 h confirmed exactly the findings of Lewis et al. (1972), indicating that subjects not given extinction to startbox cues but receiving ECS showed amnesia by committing more errors in relearning the maze than their sham-ECS controls. Also, the no-extinction-ECS group made more errors than subjects given extinction to maze cues and ECS. This latter group did not differ from its sham-ECS control, and no difference was obtained in a comparison of the two sham-ECS groups.

These same comparisons among the groups tested at 96 h failed to show statistical reliability in all cases. Additional comparisons between each groups' 24- and 96-h test performance indicated that subjects not given extinction but receiving ECS showed better retention, i.e., memory recovery, at 96 h; whereas subjects given extinction and sham ECS showed better retention in the 24-h test. The comparisons in test performance between 24 and 96 h in the remaining two groups failed to show reliable effects.

Discussion

This experiment replicated the results of Lewis et al. (1972) that ECS, when preceded by training cues, results in amnesia as determined by a retention test at 24 h. However, the present experiment also tested subjects 96 h after ECS, and the results of this test showed amnesia to be absent following ECS. Moreover, subjects given no extinction experience and ECS showed significantly better retention at 96 h compared with those tested at 24 h. This finding suggests that the amnesia induced by ECS under these conditions is transient, as memory recovered spontaneously at 96 h. This result is predicted from a state dependency point of view whereas both those who hold that motivational state (Robbins & Meyer, 1970), or "active memories" (Lewis & Bregman, 1973), interact with ECS to effect amnesia are silent with regard to the issue of memory recovery.

The finding that subjects not given ECS made more errors at 96 h than at 24 h suggests that some "forgetting" occurred with the passage of time, particularly in subjects also given extinction experience. Against this baseline, the memory recovery in the

Table 2
Mean Errors ($\pm$ One Standard Error)

Sham 24 h N = 7	ECS 24 h N = 6	FS 24 h N = 5	FS-ECS 24 h N = 7	FS-ECS 96 h N = 6
.57 ($\pm$.43)	1.83 ($\pm$.83)	1.40 ($\pm$.51)	.86 ($\pm$.26)	1.50 ($\pm$.50)

no-extinction-ECS group at 96 h reflected in fewer errors to retrain in the 96-h test is all the more impressive.

EXPERIMENT II

In this experiment, we tested whether ECS preceded by footshock would result in amnesia followed by memory recovery under the conditions of the K maze.

Method

Subject and apparatus. Subjects were 31 male Long-Evans rats of the same age and history as in Experiment I. The apparatus was also the same as that in Experiment I but also included a Plexiglas grid box which measured 20 x 23 cm and was 20 cm high. The grid floor was made of .33-cm-diam stainless steel rods, spaced 1.1 cm apart center-to-center. This grid box was placed in a different room from the K maze.

Procedure. The subjects were trained to criterion in the K maze following the same procedures outlined in Experiment I. After criterion was attained, each subject was extinguished to handling and startbox cues for 7 days. On the 7th day, each subject was individually placed in the grid box and given either scrambled footshock (2 sec, 1.3 mA, 60 Hz, 268 V rms), footshock followed .5 sec later by ECS, ECS alone, or neither footshock nor ECS. Subjects in these four groups were tested for retention of the maze 24 h later. In addition, some subjects given footshock and ECS were tested only at 96 h.

Results

Table 2 shows the mean errors required for each of the five groups to relearn the maze. The impression of no differences was confirmed by an analysis of variance ($F = .99$, $df = 4/26$, $p > .05$).

Discussion

Contrary to our previous findings (DeVietti & Larson, 1971; Deviitti, Mayse, & Morris, 1974; Mayse & Deviitti, 1971) footshock and ECS given at an extended interval following training did not result in amnesia 24 h later, and therefore the finding of retention in the footshock-ECS group in the 96-h test cannot be considered as an example of memory recovery. Failure to find amnesia in the present experiment is predicted by both motivational- and cue-dependency positions, as both the motivational state and the cues associated with footshock would seem to be quite dissimilar from food deprivation and/or maze cues.

GENERAL DISCUSSION

The results of the present experiments in conjunction with the previous literature dealing with amnesia for

long-term habits induced by ECS lead us to speculate that, under these conditions, one is dealing with at least two important questions.

The first is the nature of the stimulus which interacts with ECS to effect amnesia. The present results and the available literature are consistent with the notion that ECS, to be an effective disrupter of memory for long-term habits, must be preceded by a stimulus inherent to the training situation, e.g., training cues (Lewis et al., 1972) or motivational condition (Robbins & Meyer, 1970). If this notion is extended to include the arousal state of the organism during training and preceding ECS, the results from our laboratory in which footshock and ECS resulted in amnesia for habits acquired under conditions of water escape (DeViitti et al., 1974; Mayse & Deviitti, 1971) also seem explained.

The second question involves the nature of the amnesia effected once the proper combination of stimulus and ECS are selected. The results of Experiment I and previous work with ECS effects on long-term habits (DeViitti & Larson, 1971; Deviitti et al., 1974; Mayse & Deviitti, 1971) showed that the amnesia effected under these conditions was transient and therefore consistent with a state dependency view.

Failure to obtain transient amnesia under the conditions of the K maze was recently reported by Bregman (Note 1). Bregman replicated Lewis et al. (1972) and tested subjects at both 24 and 96 h in an experiment very similar to Experiment I of the present report. He failed to obtain memory recovery in ECS subjects in the 96-h test. However, Bregman's ECS parameters were considerably different from those used in the present experiments and our previous work, in which we have obtained memory recovery at 96 h (e.g., Deviitti & Larson, 1971; Deviitti et al., 1974). Moreover, we have shown ECS intensity to be an important parameter in determining the intervals at which the dissociation apparently dissipates, thus giving rise to memory recovery (DeViitti et al., 1974). Thus, Bregman's data are not a serious limitation to our pervasive finding of memory recovery when ECS induces an initial amnesia for long-term habits.

More data will be necessary to clarify the nature of the amnesia effected for long-term habits by ECS. However, in view of the spontaneous recovery of memory, we have consistently obtained under these conditions, e.g., Experiment I of the present report, and the fact that other reports from our laboratory have included groups which more fully allow for a state dependency interpretation of the amnesia effected (DeViitti & Larson, 1971; Mayse & Deviitti, 1971), we would tentatively argue that ECS-induced amnesia for long-term habits results from a dissociation of learning, regardless of whether the situation is designed to show the superiority of motivational condition, training cues, or arousal state as the effective stimulus interacting with ECS to produce amnesia.

REFERENCE NOTE

1. BREGMAN, N. J. *Environmental cues and electroconvulsive shock (ECS) produced memory occlusion in rats*. Paper presented at the meeting of the Southwestern Psychological Association, Dallas, Spring 1973.

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