The effect of training on ECS-induced hyperreactivity to footshock¹

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Two experiments were performed to determine if training eliminates or exerts control over an ECS-induced hyperreaction to footshock (FS) that has been observed in nonlearning, inescapable FS situations. Experiment 1 showed that ECS resulted in a proactive facilitatory effect on avoidance learning, suggesting that training exerts control over an ECS-induced hyperreaction to FS. Experiment 2 demonstrated that an ECS-induced hyperreaction to FS is brought under stimulus control through the act of training. In this experiment, ECS was given following training, and an overreaction to FS in a test situation was expressed in terms of overmanipulation of a bar previously associated with FS termination; no such overreaction was expressed in terms of manipulating a bar not previously associated with the cessation of FS.

A recent series of experiments demonstrated that within 6 to 24 h after receiving a single electroconvulsive shock (ECS), the rat overreacted to aversive, inescapable footshock (FS). The overreaction occurred even though the rat's sensitivity to FS, as indicated by threshold measurements, and activity in the absence of FS were at control levels (Misanin & Lewis, in press). Since a number of investigators interested in the effects of ECS on learning and memory have employed FS as a motivating stimulus and a 24-h ECS-test interval, it is desirable to know what role, if any, this ECS-induced hyperreactivity plays in learning experiments. It may be that in the learning situation, where FS can usually be escaped or avoided, ECS does not produce an overreaction to FS as it does in the inescapable FS situation. If it does, however, and the overreactive component of the response to FS is brought under stimulus control through the act of training, then ECS may enhance the learned response (e.g., Vanderwolf, 1963). If, on the other hand, ECS produces an overreaction to FS in the learning situation but training exerts no control over the hyperreactivity, then ECS may attenuate the learned response to FS by minimizing the rat's reaction to other stimuli specific to that response (cf. Williams, 1963).

EXPERIMENT 1³

The plan of this experiment was to provide a learning situation in which an index of the FS aversion threshold as well as measures of reactivity to above and below threshold FS would be obtained both for rats convulsed 24 h before testing and for rats not given ECS. Thus, the purpose of this experiment was in part to confirm the finding that 24 h after ECS the rat's sensitivity to FS is at control level and in part to determine whether or not ECS has the same proactive effect on reactivity to FS in a learning situation as it does in the inescapable FS situation (Misanin & Lewis, in press).

METHOD

Subjects

Eighty 200- to 250-g male albino rats of the Sprague-Dawley strain were purchased from Charles River Breeding Laboratories, Wilmington, Massachusetts. The rats were maintained on ad lib food and water prior to testing.

Apparatus

The apparatus was a 18 x 7 x 9 in. aluminum cage with a grid floor. The grids, 3/32-in. stainless steel rods, were mounted in Plexiglas at 1/2-in. intervals. The floor was arranged to tilt and operate a microswitch when the rat crossed from one end of the cage to the other. Operation of the microswitch applied FS to the floor. A fixed impedance (150,000 ohms) source was used for FS; a 12-contact 10-position stepping switch was used to systematically change the FS pattern.

The ECS was a constant voltage stimulus, 300 V, administered for .5 sec via modified alligator clips attached to the rat's ears. The ECS and pseudo-ECS (attached ear clips but no ECS) were administered outside the learning situation. All rats receiving ECS underwent a full tonic-clonic seizure.

Procedure

The Ss were randomly divided into two groups of 40 Ss each. One group received ECS 24 h before testing; the other group received pseudo-ECS. Both groups were divided into four subgroups of 10 Ss each. Each subgroup of a treatment group was tested at a different one of four FS levels (5, 10, 20, and 40 V). The test consisted of placing S in the apparatus and automatically applying FS to the floor whenever S was at one end of the cage, which S could then terminate by crossing to the opposite end of the cage. FS was applied to one end of the cage for half of

the Ss of each subgroup and to the opposite end for the other half. Time spent on the safe (0-V) side of the cage was electrically recorded for each 90-sec period of the 15-min test session.

RESULTS

Aversion Thresholds

Pilot work as well as previous research (e.g., Misanin & Campbell, 1969) indicated that Ss displayed relatively asymptotic preferences for a particular side of the cage over the last 6 min of the test session. Thus, the percentage of time spent on the 0-V side of the cage during the last 6 min of the session was computed for each S and used to obtain threshold estimates. An appropriate index of the shock-aversion threshold would be that level of shock at which Ss spend, on the average, 75% of their time on 0 V (cf. Campbell & Masterson, 1969). Figure 1 shows the percentage of time spent on 0 V at each test-voltage level for each treatment group. Because of the nature of the curve, the method of selected points (20 and 40 V) was used in determining threshold estimates. These estimates were 32.5 and 30.0 V for the control and ECS groups, respectively. A 2 by 4 analysis of variance performed on the time scores over the last 6 min of the session showed voltage to be the only significant factor ($F = 16.20$, $df = 3,72$; $p < .001$), indicating that the threshold estimates cannot be considered reliably different.

Reactivity

To obtain a measure of reactivity to above-threshold FS, the percentage of time spent on the 0-V side of the cage (percent preference for 0 V) during each 90-sec period of the test session was computed for each S in the 40-V subgroups. These percentages are shown in Fig. 2 (solid lines). The rate at which S acquired the avoidance response (AR), i.e., remained on the 0-V side 75% of the time, was considered a measure of its reactivity to

Fig. 1. Aversion threshold functions for animals convulsed 24 h prior to testing and for control (nonconvulsed) animals.

Fig. 2. Percent preference for the 0-V side of the cage for ECS and control groups during each 90-sec period of the 15-min test session as a function of shock level.

FS. Rate was determined by the number of 90-sec periods required to attain this level of avoidance. Figure 2 indicates that the ECS group shows the greater reactivity. A chi-square analysis on the number of animals in each 40-V subgroup attaining the 75% level of avoidance in the first half of the session (five 90-sec periods) showed that the ECS animals were (by this measure) significantly more reactive to FS than pseudo-ECS animals ($\chi^2 = 5.04$, $df = 1$; $p < .025$). For comparison, percentages for Ss in the 20-V subgroups are also shown in Fig. 2 (broken lines). As is evident, no overreaction to below-aversion-threshold FS occurs on the part of ECS Ss.

EXPERIMENT 24

In Experiment 1, the performance of an AR was enhanced by a single ECS given prior to training. To say that the act of training brought an ECS-induced overreaction to FS under stimulus control would, however, be conjecture, since an overreaction to FS was arbitrarily defined in terms of enhanced performance of the AR. If the act of training per se does bring an ECS-induced overreaction to FS under stimulus control, then this should also be evidenced when ECS is given following training. The present experiment explored this possibility.

METHOD

Subjects

The Ss were 16 195- to 235-g female albino rats of the Sprague-Dawley strain purchased from Camm Research Institute, Wayne, New Jersey. The Ss were maintained on ad lib food and water prior to and between sessions of the experiment.

Apparatus

The apparatus was a two-bar operant conditioning chamber, 11 x 8½ x 7½ in. The sides and top of the chamber were aluminum, and the floor consisted of 3/32-in. stainless steel grids fixed in Plexiglas at ½-in. intervals. At each end of the chamber, a 2-in.-wide stainless steel bar

protruded ¾ in. into the chamber, the upper surface of the bar being 2½ in. above the grid floor. The chamber was housed in an insulated cabinet that contained an exhaust fan and a 10-W overhead light.

The FS source, scrambler, ECS, and convulsive characteristics were the same as those described in Experiment 1.

Procedure

The Ss were randomly divided into two groups of eight Ss each and given 50 training trials on a FS escape response in the chamber. Forty-five seconds after S was placed in the chamber for training, a 115-V FS was delivered to the floor. Depression and release of one bar (RB) terminated the FS for 45 sec; depression and release of the other bar (NRB) had no effect. The RB was the same for all Ss and the inter-FS interval was 45 sec. During training, the latency to press RB was automatically recorded in 10ths of a second. Also automatically recorded was the number of times each bar was pressed throughout training. Immediately after training, Ss were returned to their home cages; 2 h later the Ss of one group (ECS) were given ECS and those of the other group (NECS) were given pseudo-ECS. Twenty-four hours after training, Ss were returned to the chamber for testing. The test consisted of 15 min of inescapable shock. The number of responses emitted on each bar during each 3-min period was automatically recorded.

RESULTS

The average reciprocal latency for the last 10 trials of training was determined for each S. A *t* test was then used to test the significance of the difference between the means of the two groups. The results indicated that the means did not differ significantly ($t = 1.88$, $df = 14$). An analysis of variance performed on the number of responses emitted on each bar during training (excluding the reinforced responses on RB) showed no significant group differences ($F = 1.16$, $df = 1, 14$) and no significant Group by Bar interaction ($F = 0.05$, $df = 1, 14$). There was a significant bar effect ($F = 15.26$, $df = 1, 14$; $p < .005$); both groups emitted more responses on RB than on NRB.

The mean number of presses on each bar per 3-min interval of the test session is shown for each group in Fig. 3. An analysis of variance performed on these data showed a significant group effect ($F = 4.74$, $df = 1, 14$; $p < .05$), a significant bar effect ($F = 40.67$, $df = 1, 14$; $p < .001$), and a significant temporal interval effect ($F = 4.67$, $df = 4, 56$; $p < .005$). There was also a significant Group by Bar interaction, the nature of which is clearly illustrated in Fig. 3 ($F = 5.28$, $df = 1, 14$; $p < .05$).

Fig. 3. Mean number of presses per 3-min interval emitted by the ECS and pseudo-ECS (NECS) groups on the bar (RB) previously associated with shock termination and on the bar (NRB) not previously associated with shock termination.

DISCUSSION

The results of Experiment 1 support the finding that ECS fails to alter the rat's FS aversion threshold and, presumably, sensitivity to FS at an ECS-test interval of 24 h, and indicate that ECS produces an overreaction to above-aversion-threshold levels of FS in a learning situation, as it does in an inescapable-FS nonlearning situation (Misanin & Lewis, in press). The results of Experiment 2 show further that the overreaction to FS produced by ECS is brought under control through the act of training. In this experiment, ECS was given following training and an overreaction to FS was, in the test situation, expressed in terms of overmanipulation of a bar previously associated with terminating shock; no overreaction to shock was expressed in terms of manipulating the bar not previously associated with shock termination (Fig. 3).

The present results confirm Vanderwolf's (1963) finding that ECS may facilitate avoidance performance. They disagree, however, with his conclusion that such facilitation results from an ECS-induced damage of the neural system underlying freezing behavior, which thus permits an early appearance of the avoidance response despite the fact that learning ability is impaired by ECS. Experiment 1 of the present study showed that Ss given ECS learn to avoid FS faster than do control Ss; however, if both freezing behavior were interfered with and learning ability impaired, the convulsed Ss should have learned to avoid FS at a slower, not a faster, rate than controls in this passive AR situation. The present results also disagree with Vanderwolf's (1963) contention that ECS-induced facilitation of an active AR is not complicated by hyperactivity or a supranormal motivation to avoid FS.

Vanderwolf (1963) reached this conclusion on the basis of earlier research (cf. Munn, 1950) indicating that ECS does not increase spontaneous or random activity. While hyperactivity in the absence of FS may not be a complicating factor, hyperactivity during FS may well be, particularly since it is brought under stimulus control during training. Also, hyperactivity during FS may be indicative of a supranormal motivation to avoid FS.

The present results are not novel in showing that ECS produces an overreaction to stimulation. This has been noted following both multiple (e.g., Brady, 1952; Stern & Williams, 1961; Williams, 1963) and single (Misanin & Lewis, in press) ECS treatments. The present results are novel in that they demonstrate that such an overreaction can be brought under stimulus control through the act of training. This finding thus has a particular relevance to studies attempting to assess the prograde amnesic effects of ECS on responses learned under FS motivation (e.g., Kopp, Bohdanecky, & Jarvik, 1967). In essence, animals trained on a response to FS 24 h after ECS may be learning a different response or a response differing in strength from that of control (nonconvulsed)

animals. This finding also calls for a reconsideration of an optimal ECS-test interval in investigations on the retrograde amnesic effects of ECS, particularly when the test response involves FS (e.g., Duncan, 1949).

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NOTES

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2. Reprint requests are to be sent to James R. Misanin, Department of Psychology, Susquehanna University Selinsgrove, Pa. 17870.

3. Experiment 1 is from a thesis submitted by the first author to Rutgers University in partial fulfillment of the requirements for the PhD degree.

4. Experiment 2 was conducted while the authors were at Princeton University.

The independence of barpressing and schedule-induced drinking*

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In a study of schedule-induced polydipsia in rats, water was not made available within the operant chamber until magazine and barpress training and adaptation to the intermittent schedule were completed. A gradual development of schedule-induced drinking without corresponding changes in barpressing behavior was seen. In a second experiment, rats differing in the number of barpresses emitted on two temporally similar fixed-interval schedules did not differ significantly in volumes of water consumed during interpellet intervals. Both studies demonstrate the independence of barpressing and schedule-induced drinking.

Studies of schedule-induced polydipsia (SIP) employing a barpress contingency typically have been designed so that animals have access to water from initial training to final steady responding on an intermittent reinforcement schedule (e.g., Falk, 1961). Increases in water consumption during the course of several such sessions often appeared to be correlated with change in barpressing behavior as the animals adjusted to the

schedule requirements. The apparent close relationship between the two behaviors, drinking and barpressing, led to speculation concerning their functional, although adventitiously maintained, relationship (Clark, 1962; Mottin, 1969; Shanab & Peterson, 1969).

Other studies (Schaeffer, Diehl, & Salzberg, 1966; Freed, Carpenter, & Hymowitz, in press) suggested that barpressing and drinking were independent behaviors. Manipulation of independent variables (reinforcement contingencies, acquisition and extinction parameters, and drug effects) affected barpressing and

drinking differentially. The studies reported in this paper further analyzed the independence of barpressing and drinking during polydipsia. In Experiment 1, water was not introduced into the chamber until barpressing behavior was well established. In Experiment 2, SIP was studied in rats that were exposed to reinforcement schedules of similar temporal dimension but with different discriminative cues for the barpress response.

EXPERIMENT 1

Subjects and Apparatus

The Ss were three male albino Sprague-Dawley rats weighing between 200 and 250 g at the start of the experiment. Animals were housed in individual home cages and were maintained on Purina Lab Chow. Water was available ad lib in the home cage throughout the experiment. A standard sound-attenuated Grason-Stadler operant chamber programmed by solid-state equipment, a Plexiglas rat lever that could be illuminated, and a 50-ml Richter tube were employed.

Procedure

Following 7 days of weight reduction to 80% of free-feeding body weight, Ss were introduced into the operant chamber for magazine and barpress training. An empty Richter tube was located within the chamber. After S's first barpress, which was immediately followed by consumption

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