ECS-induced retrograde amnesia indicated by a heart-rate measure of retention*

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Rats that received a single fear conditioning trial consisting of a tone followed by footshock showed marked heart-rate deceleration both during and following the presentation of the tone the next day. Groups that received either the fear conditioning trial followed by ECS, the tone followed by ECS, or neither the fear conditioning nor ECS showed little, if any, conditioned heart-rate deceleration during the test trial. These data provide evidence that ECS can effect retrograde amnesia when an autonomic index of retention is employed.

When ECS is administered to rodents shortly after a training trial, retrograde amnesia (RA), as indexed by some voluntary behavior pattern of the animal at the retention test, typically results (Lewis, 1969). Recent explanations of ECS-induced RA have taken several forms, including memory storage disruption (McGaugh, 1966; McGaugh & Dawson, 1971), memory retrieval failure (DeVietti & Larson, 1971; Nielson, 1968), motor disinhibition (Adams & Peacock, 1967), and disruption of the conditioned emotional response (Spevack & Suboski, 1969). Regardless of the explanation of the effect, behavioral indices have consistently demonstrated that ECS causes RA. On the other hand, studies that have used autonomic indices of retention, defecation (Mendoza & Adams, 1969), and heart rate (Mendoza & Adams, 1969; Hine & Paolino, 1970) have failed to show that ECS induced RA. Thus, the behavioral and autonomic indices of retention appear to be at odds in the determination of whether or not ECS produces RA.

Since the number of studies employing autonomic measures of retention following ECS is quite limited, the present study was performed to provide more information on this important question.

SUBJECTS

The Ss were 20 Long-Evans male rats from the Central Washington State Psychology Department colony, aged 90-120 days at the start of the experiment. They were individually housed and maintained on Purina Lab Chow and water ad lib.

APPARATUS AND PROCEDURE

The training and testing chamber

was a Lehigh Valley Electronics test chamber (Model 1417) with the manipulanda removed. The chamber was enclosed in a lighted fan-ventilated sound-attenuating box. Heart rate was recorded with E and M surface electrodes embedded in a harness, which was fastened around the body of the S just before the daily experimental sessions. An E and M transmitter attached to the ceiling of the training test chamber, an E and M receiver, and a Brush recorder completed the heart-rate recording equipment.

The Ss were fitted with the electrode harness daily and handled for 3 successive days. During these sessions, small alligator clips were attached to their ears. On each of the next 2 days, the Ss were fitted with the electrode harness and individually placed in the training chamber for 5 min. Heart rate was recorded for 30 sec, commencing 1 min after placement in the chamber. On the next day, fear conditioning and ECS treatments were given by a different E, who assigned the Ss randomly, five each, to one of four groups and carried out the group assignments as follows: Ss in Group TFS-ECS were placed individually into the chamber, with ECS leads (small alligator clips) attached to their ears. After 1 min, a 15-sec 1,200-Hz tone was presented via a 6-in. loudspeaker positioned at floor level behind the back wall of the chamber. During the last 3 sec of the tone, a scrambled current of 1.3 mA (60 Hz, 268 V rms) was presented through the grid floor of the chamber. ECS (.2 sec, 92 mA, 60 Hz, 1,840 V rms) followed .5 sec after the termination of tone and grid shock. Ss in Group TFS were treated identically, except that they did not receive an ECS. Group T-ECS Ss were presented just the tone, followed by ECS. Finally, Ss in Group N received neither the tone-grid shock nor the ECS. All Ss were tested 24 h later by the original E, who was uninformed as to the group assignment of the Ss. The Ss

were placed in the chamber, and the 15-sec tone was presented 5 min later. Heart-rate recordings were taken for 30 sec, both 1 min after placement into the chamber and again 30 sec prior to the presentation of the tone. Recording continued through the tone presentation and for 1 min thereafter. Tabulation of heart rate was performed by counting the number of beats for all recorded intervals and was done without knowledge of the Ss' treatment conditions.

RESULTS

A repeated-measures analysis of variance was performed on the 30-sec heart-rate data obtained 1 min after entry into the training-test chamber on each of the 2 adaptation days preceding differential group treatment and the test day. This analysis revealed only a test day effect ($F = 8.45$, $df = 2/32$, $p < .01$). A Newman-Keuls test showed that there was a heart-rate decrease on the test day compared to the 2 adaptation days. Since neither the groups effect nor the Groups by Test Days interaction proved reliable, it must be concluded that this measure, reflecting fear conditioned to situational cues, did not differentiate among the treatment groups.

Suppression ratios (DeVietti & Porter, 1969, 1970) were calculated for each S from the heart-rate recordings taken at the test day. This transformation compared heart-rate changes for each of five successive 15-sec epochs, beginning with the presentation of the tone and concluding 1 min after the tone offset, to the heart rate obtained during the 30-sec epoch just prior to tone onset. With this transformation, no change in heart rate between the 30-sec pretone epoch and any 15-sec epoch yields a ratio of .500; heart-rate decreases are reflected by ratios less than .500. Figure 1 shows the suppression ratios of the four groups at each of the five 15-sec epochs. A repeated-measures analysis of variance of these data showed that the groups did not differ ($F = 3.07$, $df = 3/16$, $p > .05$). However, both the epochs and the Epochs by Groups interaction proved to be reliable sources of variance ($F = 3.64$, $df = 4/64$, $p < .01$; $F = 1.97$, $df = 12/64$, $p < .05$, respectively). The breakdown of the simple main effects of the interaction (Kirk, 1968) and appropriate Newman-Keuls tests confirmed the impression given in Fig. 1 that the TFS group showed marked heart-rate suppression to the presentation of the tone and that this suppression gradually returned toward pretone levels during the ensuing epochs. Also, the TFS group showed more suppression ($p < .05$) at the first two epochs than did the other three

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Fig. 1. Effect of treatments on heart-rate suppression at recorded epochs.

groups, which did not differ from one another.

DISCUSSION

The results of this experiment indicate that ECS induced RA when an autonomic response, heart rate, served as the indicator of retention. That this was the case receives a good deal of support from the fact that RA has consistently been obtained in this situation, with the same FS and ECS parameters, when suppression of drinking (a voluntary response) served as the retention measure (unpublished observations). Thus, in this conditioning situation, ECS-induced RA is reflected by either skeletal or

autonomic measures of retention.

The very many procedural differences between this study and those reporting a failure of ECS to produce RA with heart-rate retention measures (Hine & Paolino, 1970; Mendoza & Adams, 1969) make explanation of the contrary results inconclusive at this time.

The present results, while demonstrating ECS-induced RA, shed no light on the mechanism by which ECS disrupts memory processes. Rather, the contribution of this study, as well as that of Davis & Holmes (1971), who reported ECS-induced RA with an autonomic response in

goldfish, is a demonstration that, under some circumstances, ECS can induce RA when autonomic indices of retention are employed.

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