Hippocampal disruption and passive avoidance behavior

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The behavior of rats receiving constant electrical stimulation of the hippocampus was compared with that of hippocampectomized and unoperated control rats on a task requiring inhibition of a punished approach response. No significant differences appeared in the number of shocks accepted during training although operated Ss showed significantly shorter approach latencies following shock. The results support the hypothesis that electrical stimulation is capable of disrupting the function of those structures involved in response inhibition.

Lesions of the hippocampus (e.g., Isaacson & Wickelgren, 1962) and constant septal stimulation (Kasper, 1964) have been shown to decrease passive avoidance behavior. Kasper suggested that septal stimulation produced an avoidance deficit by disrupting a response inhibition circuit in which the hippocampus is critical. The purpose of the present study was to compare the effects of constant electrical stimulation of the hippocampus with removal of that structure on behavior in a passive avoidance situation.

SUBJECTS, SURGERY, AND HISTOLOGY

Thirty male hooded rats, approximately 120 days old at the start of testing, served as Ss.

All surgery was performed under Sedax anesthesia supplemented with .2 cc of atropine sulphate. One group (HpL, N = 8) sustained bilateral lesions of the hippocampus through a bipolar electrode insulated except at the tip and powered by a Model 3 Grass Lesion Maker. Ten Ss (HpESB) were chronically implanted with bipolar electrodes aimed at three locations in the dorsal hippocampus. Implanted Ss were tested for intracranial self-stimulation in a lever-pressing apparatus. On the basis of seven shaping sessions, no animal was found to press more than seven times in any 10-min session. Twelve Ss (Group C) served as unoperated controls. All Ss were individually housed and, following a 30-day recovery period, were placed on a 23-h water-deprivation schedule.

When testing was completed, operated Ss were sacrificed and perfused with a 10% formalin solution. The brains were removed, imbedded in celloidin and sliced at a

Table 1
Avoidance Performance of Hippocampally Lesioned, Stimulated and Control Ss.

Group	N	No. Fs accepted		Postshock latency (sec)	
		Mean	Range	Median	Range
HpL	8	8.5	1-21	18.0	4.6-600
HpESB	10	9.7	3-28	80.9	7.9-269
C	12	4.9	1-16	525.9	2 -600

thickness of 50 microns. Representative sections were stained with cresyl fast violet, mounted and photographed (see Fig. 1). Sections from other Ss were mounted unstained.

APPARATUS

The Ss were tested in an 8 x 12 in. Plexiglas chamber with a grid floor. The spout of a Richter bottle projected from the middle of one wall and was connected through a touch-sensitive relay to a timer which, in turn, controlled a scrambled shock source set to deliver approximately .5 mA of foot-shock (FS). Group HpESB received constant 20-microampere 100-Hz square waves, .5 msec in duration, from a Grass S4 stimulator. Cross talk between ESB and FS was minimized by the use of short cables, isolated ESB and FS sources, and a low-level ungrounded FS current.

PROCEDURE

The Ss were given seven daily preshock sessions of 10 min during which the drinking tube was accessible in the test chamber.

These sessions were followed by 30 min of drinking in the home cage. Group HpESB received brain stimulation during all sessions. On the eighth day, the electrical circuit was closed so that S would receive FS as it began drinking. The session lasted 10 min and each time S returned to drink, another FS was delivered. The number of shocks accepted was recorded. The Ss were then given 30 min access to water in the home cage. Twenty-four hours later, S was placed in the apparatus and latency of the first contact with the drinking spout was recorded. No FS was given during this retention session. The trial was terminated if S did not make contact with the drinking tube within 10 min.

RESULTS AND DISCUSSION

Table 1 indicated that hippocampally disrupted Ss (lesion or ESB) showed less avoidance of the punishing water spout than control Ss. Although operated Ss accepted more shocks during the training session, this measure did not reach statistical significance.

Fig. 1. Photomicrographs showing the electrode placements and the extent of lesions in representative sections. Electrode coordinates are the following: P 3.0 mm, L 2.5 mm, V 3.5 mm; P 3.0 mm, L 2.0 mm, V 2.5 mm; P 3.0 mm, L .5 mm, V 4.0 mm. P is posterior to bregma, L is lateral to midline, and V is measured below the top of the skull.

($F = 19.0$, $df = 2/27$, $p > .05$). The postshock approach latencies for the operated Ss were also shorter, and only one (5%) of these Ss avoided the spout compared to five (42%) of the control Ss. The Kruskal-Wallis one-way analysis of variance by ranks (Siegel, 1956) performed on postshock approach latencies for the three groups was statistically significant ($H = 8.25$, $p < .05$). A planned Mann-Whitney test on approach latencies was performed between Groups HpL and HpESB. No significant difference was found between the two operated groups ($z = .62$).

Examination of electrode placements indicated that in at least one S (CA33-6 in Fig. 1), the electrode was stimulating the cortex dorsal to the hippocampus. This S accepted the fewest shocks and had the longest postshock approach latency in Group HpESB. Other comparisons between electrode locus and performance revealed that those placements which were most likely stimulating the hippocampus produced the greatest deficits in avoidance. There was similar agreement between the extent of damage in Group HpL and avoidance behavior. For example, the S with the most hippocampal tissue remaining (some dorsal, most ventral) was the only operated S that did not approach the water spout during the retention session.

The results indicate that changes in passive avoidance behavior produced by electrical stimulation are similar to those observed in hippocampally lesioned rats. The present findings are in accord with the view (Kasper, 1964) that constant stimulation of certain related limbic structures is capable of disrupting a circuit which mediates response inhibition. Differences in response inhibition may also have resulted from an increased drinking tendency on the part of experimental Ss (Kimble & Coover, 1966). The contribution of consummatory factors might be assessed by removing ESB during the postshock retention test.

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NOTE

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Varying temporal relationship of an intruded aversive stimulus with time-out from responding¹

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Four groups of rats were trained on a random-interval schedule of positive reinforcement. During daily sessions successive 2-min exposures to the schedule were interrupted by 2-min time-outs during which the lever operandum was withdrawn from the chamber. Response-independent shock was superimposed in different portions of the behavior stream for different groups so that one group was shocked in the middle of the reinforced periods, one at the end of the reinforced components, one group in the middle, and one group at the end of the time-out components. Animals shocked during or at the end of the reinforced component were suppressed by lower intensity shocks than were rats shocked outside the periods of bar-pressing. The results are consistent with several different conceptual schemes.

Farmer & Schoenfeld (1966a) have reported an experiment involving an "irreducibly primitive paradigm for exploring stimulus effects on steady-state responding." In that study, the position of an intruded stimulus was varied systematically within a 1-min fixed-interval schedule of positive reinforcement. The degree of control exerted by the stimulus was considerable, and was closely related to the time of its intrusion. An earlier study by Flanagan & Webb (1964) had similar results and, in a second experiment, Farmer & Schoenfeld (1966b) demonstrated that response-independent stimulus onset at different portions of a fixed-interval schedule also exerted control over responding. These studies demonstrate that the stimulus intrusion paradigm can resemble both that of conditioned reinforcement and of discriminative stimuli.

The present experiment extends the paradigm to the case where the intruded stimulus is "aversive" (electric shock). The stimulus intrusion was effected during times when the behavior stream was dominated by a positively reinforced prespecified response (R, bar-pressing by rats), and during the times when nonspecified behavior other than bar-pressing (not-R) was in progress. In this case the paradigm can be seen to resemble the procedures of delay of punishment and of conditioned suppression.

SUBJECTS

The Ss were 16 male albino rats, 150-200 days old, maintained at 80% of their free-feeding weights at the start of the experiment by water deprivation. Food was always available in the home cages, while sufficient water to maintain the desired body weight was given immediately following the sessions.

APPARATUS

The experimental chambers were Scientific Prototype rat chambers (Model A100) fitted with retractable levers. A 2-kHz, 75-dB tone was presented through speakers mounted directly above the experimental chambers. The speakers and chambers were enclosed in sound-attenuating shells (Scientific Prototype Model 300). The reinforcement was 0.01 cc of Alba skim milk, presented for 4 sec. Experimental contingencies and data recording were programmed on a digital computer (Snapper, Knapp, & Kushner, 1967). The shock was 325 V ac, distributed to the grids by a grid scrambler described by Snapper (1966).

PROCEDURE

The rats were randomly divided into four groups of four rats each. After initial "shaping" of the bar-pressing response, they were exposed to the baseline schedule, which consisted each day of 30 2-min periods comprising a 1-h session. In the first period and alternate periods following it (i.e., the third, fifth, seventh, etc.), the bar