Response inhibition of rats with medial and lateral septal lesions

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Ten male albino rats were shaped to bar press for food pellets and placed on a differential reinforcement of low-rate (DRL) schedule to investigate the effects of lesions in medial septal rats and lateral septal rats on response inhibition. All Ss in both experimental groups, including those that failed to meet the 50% response reinforcement criterion, did show a gradual and distinct acquisition curve. For all groups, as training progressed, an attenuation in response rate was accompanied by an increase in number of reinforcements. Mann-Whitney U tests indicate that the differences between the control group and each experimental group were significant at the .05 level. No significant differences were found between the medial septal group and the lateral septal group.

Several investigations have attempted to determine the effects of septal lesions upon bar-pressing behavior of rats on a temporal discrimination schedule for food reinforcement. Two factors of interest are the loci of ablation, and the various differential reinforcement of low rate (DRL) schedules employed by investigators. Ellen, Wilson, & Powell (1964) found that rats in which only the medial septal area had been ablated showed impairment in acquisition of DRL performance. On the other hand, Caplan & Stamm (1967) found that acquisition of DRL behavior in animals with septal lesions in both the medial and lateral regions

depend upon the training method employed, and the specific delay interval required for reinforcement. Septal rats placed directly on a DRL-20, the abrupt method, failed to inhibit timing behavior, whereas septals that were placed on a DRL-6 schedule did learn to inhibit their responses. If the DRL contingency is lengthened by small discrete steps as the animal improves his timing behavior at each preceding one, it will acquire a DRL-20 (Caplan & Stamm, 1967). Further, Harvey & Hunt (1965) reported that medial septals performed at least as well as normals when working for water on a gradually increasing DRL contingency.

The present study was conducted to determine the extent to which each septal region, medial or lateral, disrupts acquisition of response inhibition (timing behavior) as measured in terms of differential reinforcement of low-rate performance in the rat.

SUBJECTS

Twelve male Sprague-Dawley rats, 120 days old, were obtained from the Rush Laboratories. Four rats were randomly assigned to the control group, four to the medial septal group, and four to the lateral septal group. One rat assigned to the lateral septal group expired while being anesthetized for the operation and was immediately replaced by one of the reserves; another rat was dropped from the medial group after histological examination.

APPARATUS

The apparatus consisted of two conventional operant boxes, each placed in a sound deadened chamber equipped with a circulating fan and white noise, which served as an

auditory mask. Standard relay equipment was used to program all reinforcement contingencies. The reinforcers were 45-mg Noyes pellets, and were given under the contingency of a DRL 15-sec schedule. The responses and reinforcements were recorded on counters.

PROCEDURE

Following a 23-h food-deprivation period all Ss were initially shaped to bar press for a food pellet. They were then placed on a continuous reinforcement schedule for 1 h. Subsequent to preliminary training, each S assigned to the medial or lateral septal group was administered an ether anesthetic and placed in the Stellar-type stereotaxic apparatus. The de Groot (1959) Brain Atlas was used for reference coordinates. Lesions were made bilaterally in the predetermined area of the septum following the standard procedures. For the lateral and medial septal lesions, a direct current of 3 mA was administered for 15 sec. The medial septal lesions were placed 1.9 mm in front of Bregma, ± 5 mm lateral to the sagittal suture, and 6.5 mm below the surface of the skull at this point. The lateral septal lesions were placed 2.3 mm in front of Bregma, ± 1.0 mm lateral to the sagittal suture, and 5.0 mm below the surface at this point. The control rats were subjected to similar operative procedures, but did not receive any electric current. After the operation the Ss were placed in metabolism cages on food and water ad lib for a recuperation period of 7 days.

One day prior to the initiation of the DRL schedule all Ss were again subjected to 23 h food deprivation, after which each S was placed in the operant chamber on the DRL 15-sec schedule. Each S continued on that schedule until reaching the final criterion performance of three consecutive 50-min daily training periods in which the S

AFTER DEGROOT, 1959
A 7.8

AFTER DEGROOT
A 8.2

Fig. 1. Reconstruction of a medial septal lesion (left) for S 6 and a lateral septal lesion (right) for S 7.

Fig. 2. Acquisition of DRL behavior by the medial septal, lateral septal, and control groups. Criterion is denoted by the circle around respective rat symbols.

received reinforcements on at least 50% of the responses, or until 70 days had elapsed.

As each S attained criterion, it was sacrificed, perfused with 10% formalin, and had its brain removed for histological examination. If a S had not reached criterion by the 70th consecutive day, it was also sacrificed and put through the same procedure.

RESULTS

Anatomical Findings

All medial and lateral septal lesions were verified histologically. The lesions as presented in Fig. 1 represent coronal sections of the brain for S 6 and S 7. The medial septal group sustained extensive bilateral damage to the medial septal nuclei and slight damage anteriorly to the diagonal band of Broca, anterior commissure, lateral parolfactorial area, lateral septal nuclei, posteriorly to the bed nucleus, hippocampal commissure, triangular septal nucleus, and the postcommissural columns of the fornix. The rank order from the least to the greatest extent was 11, 5, and 6. The lateral septal group sustained extensive bilateral damage to the lateral septal nuclei and slight damage anteriorly from the area of the medial septal nucleus and diagonal band of Broca ventrally to the corpus collosum dorsally, the Horns of Ammon, and unilaterally to the caudate putamen. Posteriorly, damage was limited to the bed nucleus, hippocampal commissure, the triangular septal nucleus, and the columns of fornix. The rank order from the least to the greatest extent was 8, 9, and 7.

Behavioral Findings

All lesioned Ss, including those animals that failed to meet the 50% criterion, did show a gradual and distinct acquisition curve. It can be seen that two of the medial septal animals reached criterion in 28 and 34 days, respectively, while the third did not. One lateral septal rat reached criterion in 30

days, while the two remaining Ss did not. All controls acquired the DRL-15 schedule in the mean time of 22.25 days. Mann-Whitney U tests indicate the differences between the control group and each of the experimental groups were significant (both $U_s = 1$, $n_1 = 3$, $n_2 = 4$, $p = 0.05$). No significant differences were found between the medial septal group and the lateral septal group ($U' = 2.5$, $n_1 = 3$, $n_2 = 3$, $p = 0.20$).

On the first day of training a high rate of response was present in all groups of animals with relatively infrequent occurrence of reinforcement. As training progressed, the response rate decreased in all groups. For all groups this attenuation in response rate was accompanied by an increase in the number of reinforcements. For each group, Mann-Whitney U-tests produced significant differences between the total number of responses on the first day and the last day ($p = 0.05$). Also, the increase in number of reinforcements on the last day's from that of the first day's session was significant ($p = 0.05$).

DISCUSSION

The data of the present study attempted to ascertain the extent to which lesions in the medial or lateral septal region would disrupt response inhibition as measured in terms of DRL performance. Contrary to the findings of several investigators (Ellen et al, 1964; Burkett & Bunnell, 1966), severe impairment was not evident in the present

study. Lesions limited to the septal area only impeded the acquisition of DRL performance as shown by the decreased rate of response and increased rate of reinforcement. A possible explanation may be the minute size of lesions sustained in the septal area. Others have reported considerably larger lesions that destroyed not only the intended area but disrupting pathways which may mediate the animal's ability to inhibit responses. It is evident from a number of studies (Brady & Nauta, 1953; Fox, 1940; Powell, 1963) that septal nuclei receive connections from the olfactory bulb, frontal region, amygdala, olfactory tubercle, hippocampus, thalamus, and hypothalamus, etc. Destruction of these efferent pathways could very well effect the findings of impairment reported by other investigators. It should be pointed out that in the present study no successful lesion avoided some degree of invasion of the medial or lateral septal area. Ellen & Powell (1962) found that small hippocampal lesions decrease the response rate under the fixed-interval schedule, indicating that the disturbance of the function of this structure by septal damage is not the critical factor in producing the terminal response rate increase. If the many seemingly contradictory studies in the literature were ordered on a continuum of lesion size, it might be found that the larger the lesion the greater the deficit in response inhibition.

Table 1
The Means for the Total Number of Responses and Reinforcements Obtained by Each Group of Animals on the First Day and the Last Day of the Acquisition Period

Group	First Day Mean Totals		Last Day Mean Totals	
	Responses	Reinforcements	Responses	Reinforcements
Controls	366	54.50	153.75	80.75
Medial Septals	572	24.67	191.33	48.67
Lateral Septals	617.67	36.67	245.33	69.33

Employment of the DRL 15-sec schedule by the abrupt method as defined by Caplan and Stamm did not prevent the septal animals from learning to inhibit reinforced responses. According to Ellen et al, if a bar-press response can be inhibited beyond 10 sec then that is evidence of temporally dependent bar pressing. Such is the case in the present experiment. This suggests that a considerable part of the septal inhibitory influence is mediated through other parts of the limbic system as well. Earlier findings of Kimura (1958), Isaacson & Wickelgren (1962), and Kimble (1963) seem to establish the fact that hippocampally lesioned animals show decreased ability to inhibit certain kinds of responses. But as of now, the literature involving the septal and hippocampal structure is inconclusive.

The findings of this study raise a question about the explanation of septal impairment in terms of a deficit in the ability to withhold a response (McCleary, 1961).

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reduced when Ss were turned 360 deg once during the intertrial interval, and eight horizontal turns eliminated alternation behavior completely. Douglas assumed that horizontally turning an S acted to disrupt normal semicircular canal functioning.

EXPERIMENT 1

The primary purpose of this study was to investigate the effects of a 360-deg turn on subsequent choice-point behavior. One may consider the last quarter of a CW turn a 90-deg easterly/right turn when the start box is placed at the south end of the maze; a subsequent alternation response would be a westerly/left turn at the choice point. A second hypothesis to be tested concerned the very short-term memory of rats. If rats rely on a very short-term memory capacity in SAB, then moving the start box more proximal to the choice point should decrease the ITI and thereby increase the tendency to alternate.

Method

The Ss were 50 140-day-old male albino rats of the Sprague-Dawley strain purchased from Holtzman Company, Madison, Wis. Nineteen of the animals had served as Ss in a straight-runway study, 15 Ss had been in a T-maze experiment, and 16 Ss were naive.

A single-unit, undifferentiated open-roofed T-maze was used. The dimensions of the T-maze were as follows: all alleys were 5½ in. wide and 14 in. high; goal alleys were 24 in. long; the start stem, and the start boxes located within the start stem, were 18 and 8½ in. long, respectively. A hand-operated guillotine door was placed between the start box exit and the start stem. When the start box was placed at the rear of the start stem (SBR) there was about 12 in. between the guillotine door and the center of the choice point. When the start box was placed forward (SBF) there remained only 3 in. between the start box guillotine door and the center of the choice point.

All rats were placed on an ad lib feeding schedule 10-14 days preceding the experiment. The animals were run under conditions of 20- to 21-h food deprivation without reinforcement in a T-maze which contained the start box at the north end of the start stem. Twenty-five Ss were randomly assigned to the SBR condition and the remaining 25 Ss to the SBF condition during Test Trial 1. Test Trial 2 consisted of the 25 SBR (SBF) Ss run under the SBF (SBR) conditions; Ss were tested in an alternate manner four times in the SBR and four times in the SBF conditions, generating a total of 200 possible alternation observations. The time between replications was about 45 min per S.

An alternation test consisted of placing the rat in the start box, allowing 2 min for the animal to circle 360 deg, and

A note on spontaneous alternation behavior¹

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On Test Trial 1 rats placed in a T-maze start box were allowed to turn once, 360 deg, either in a clockwise or counterclockwise direction. Test Trial 2 consisted of allowing an S to traverse the T-maze. Statistically significant alternation behavior was observed between the Test Trial 1 start-box turn and the Test Trial 2 choice-point turn.

While investigating the effects of maintenance schedules on T-maze discrimination reversal problems, Richman

and Tessnear observed that a rat's choice-point turn could be predicted from the animal's initial behavior in the start box.² For example, if an S circled 360 deg in a clockwise (CW) fashion and the start box was located at the north end of the start stem, animals showed a strong tendency to turn east/left at the choice point. Likewise, animals that circled counterclockwise (CC) in the SB turned west/right at the choice point.

Douglas (1966) found that satiated rats demonstrated spontaneous alternation behavior (SAB) to directional cues, a finding since replicated by Richman, Juels, Peckinpugh, & Stutz (1969) under moderate drive conditions. Douglas (1966) also demonstrated that the level of SAB was