The effect of medial thalamic lesions on acquisition of a go, no-go, tone-light discrimination task

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Rats with bilateral lesions of either the anterior, central, or posterior dorsomedial thalamus or with sham operations were compared on the acquisition of a food reinforced, tone-light, go/no-go discrimination task in an operant chamber. Rats with small lesions of the central portion of the medial thalamus (centered on the dorsomedial nucleus) were found to be deficient relative to rats with sham or small anterior medial thalamic lesions.

It is now well established that in rats large lesions of the medial thalamus produce deficits on acquisition of both appetitive (Means, Harrel, Mayo, & Alexander, 1974; Means, Hunt, Whiteside, & Bates, 1973; Means, Huntley, Anderson, & Harrell, 1973) and aversive tasks (Vanderwolf, 1971). Several studies involving relatively small lesions restricted to either the dorsomedial nucleus (MD) or the centromedian-parafascicular complex (CM-Pf) have also resulted in behavioral deficits. Tigner (1974) has reported deficits on acquisition of brightness and tactile discrimination in rats with lesions limited primarily to the MD. Lesions centered on the CM-Pf have been shown to produce deficits on avoidance problems (Alexinsky, Delacour, & Libouban, 1971; Alexinsky & Houcine, 1973; Delacour, Libouban, & Martinez, 1965; Delacour & Santacana, 1967), complex maze acquisition (Delacour, Libouban, & Martinez, 1965), temperature discrimination (Finger & Frommer, 1970) and DRL-20 (Alexinsky & Housine, 1973).

The purpose of the present study is to examine the effects of relatively small bilateral lesions placed in the anterior, central, or posterior portions of the medial thalamus on a tone-light compound stimulus operant discrimination task. The centrally placed lesion was centered on the MD, and the posteriorly placed lesion was centered on medial portions of the parafascicular nucleus.

METHOD

Subjects

Forty 90-day-old Long-Evans rats were used in the present study. The rats were housed in individual cages with a 14-h light, 10-h dark cycle and had water available at all times.

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Surgical and Histological Procedures

Surgery was performed using Nembutal for the anesthesia. Bilateral lesions were made by passing 2.0-MA anodal direct current for 12 sec through stereotaxically placed stainless steel electrodes. The animals were positioned in the stereotaxic instrument with the top of the incisor bar elevated 5 mm above the ear bar. Bregma was used as the A-P reference point, and the top surface of the skull as the D-V reference point. The coordinates used for the three different lesion groups were as follows: anterior lesion (Group A) A-P = -2, L = ± 1.0 , D-V = -6.3; central lesion (Group C) A-P = -1.2, L = ± 1.0 , D-V = -6.3; posterior lesion (Group P) A-P = -2.2, L = ± 1.0 , D-V = -6.3. Sham operated animals (Group S) had the electrodes lowered to one of the above sets of coordinates in the brain but received no current. All animals received .20 cc of Bicillin at the onset of surgery.

Following completion of behavioral testing, the brain was removed from all experimental animals and sectioned at 50 microns in approximately the same plane as the plates in Pellegrino and Cushman's (1967) atlas. Every fourth section throughout the extent of the lesion was photographed with Kodak High Contrast Copy Film. The negatives of the lesions were then projected onto plates from Pellegrino and Cushman's atlas, which permitted determination of size and locus of the lesions.

Behavioral Procedures

Following surgery, all rats were allowed to recuperate for 14 days and then placed on an 85% ad-lib weight food deprivation schedule. Behavioral training was then initiated in three identical operant chambers that measured 23 x 21 x 20 cm and had the food magazine located next to the lever. The animals were trained on CRF until they accumulated 275 reinforced responses before go/no-go discrimination training was initiated.

Each trial of discrimination involved a 20-sec illumination of the chamber by the house light and was followed by a 10-sec ITI during which the house light was off. On all go trials, the cue light over the lever was illuminated, and an approximately 72-dB tone with a fixed frequency of approximately 300 Hz was presented. Neither the cue light nor the tone was presented during the no-go trials. The go and no-go trials occurred in a random order. On go trials all barpresses were reinforced with .45-mg Noyes pellets. No barpresses during either the no-go trials or the ITI were reinforced. All rats were trained to a criterion of three successive sessions during which both the latency and response ratios were less than .50, or until they received 30 sessions (600 trials), whichever occurred first. The latency ratio was defined as the mean latency to the first response on each of the 10 go trials/the mean latency to the first response on the 10 no-go trials. The response ratio was defined as the total responses

Figure 1. Reconstructions of a typical lesion from each group. Group A is shown in the top row, Group C in the middle row, and Group P in the bottom row.

on the 10 no-go trials/the total responses on the 10 go trials. Note that each ratio was defined such that a decrease in value indicates an improvement in performance.

RESULTS

Histological

A reconstruction of a typical lesion in each of the three experimental groups is shown in Figure 1. The Group A lesions were centered just anterior to the MD with the most consistent bilateral damage occurring in the paraventricular, anteromedial, and anteroventral nuclei of the thalamus. All animals in Group A also had some damage to the stria medullaris, and three animals had slight damage to the MD. Three rats were dropped from Group A because the histology revealed that the lesions were exceedingly small or unilateral.

The lesions of the rats in Group C were centered on the MD with all animals sustaining MD damage. Four of the eight animals in Group C also had slight bilateral damage to the paraventricular nucleus and the stria medullaris. One rat in Group C was switched to Group P because its lesion was found to be more posterior than intended.

The Group P lesions were centered on the parafascicular nucleus (Pf) and habenula complex with all rats in the group sustaining bilateral damage to both of these structures. Three or more of the animals in Group P also had some bilateral damage, usually slight, to the paraventricular nucleus, MD, stria medullaris, and posterior commissure. Two rats were dropped from Group P due to improper lesion placement.

In general the lesions were relatively small, with overlap in the nuclei damaged by the lesions to the three groups. The overlap in the lesions of Groups C and P was quite extensive.

Behavioral

Three rats were dropped from the study due to illness or failure to run in the maze, leaving six rats in Group A, eight in Group C, nine in Group P, and nine in Group S upon which the following data are based. The median and range of the number of sessions to latency-response (both latency and response rates less than .50 on three consecutive days), response (response ratio less than .50 on three consecutive days), and latency (latency ratio less than .50 on three consecutive days) criteria for all groups are shown in Table 1. Kruskal-Wallis analysis on all three criterion measures produced essentially the same results, with the groups differing significantly on all three measures (latency-response, $p < .02$; response, $p < .05$; latency, $p < .01$). A Mann-Whitney followup test further revealed that Group C is deficient relative to Groups A and S on both the latency-response and response criterion measures (see Table 1). On the latency criterion, Group C is deficient relative to all three of the other groups. Thus, the results of the analyses form a consistent pattern. Group C is deficient relative to Groups A and S on all measures, and Group P falls between Groups C and S on two of the three measures. Thus, Group C is clearly deficient on the task, and Group P is marginal.

Behavioral-anatomical relationships

Product-moment correlation coefficients between the percent bilateral damage to each of the thalamic nuclei in the lesioned animals and the number of sessions to the latency-response criterion, the primary behavioral measure, were computed. Only the damage to the MD ($r = .70$, $df = 21$, $p < .001$) and Pf ($r = .37$, $df = 21$,

Table 1
Median and Range of the Number of Sessions to Latency-Response, Response, and Latency Acquisition Criteria

Group	Statistic	Criterion		
		Lat-Res	Response	Latency
Anterior	Median	9.5	7.0	9.5
	Range	3-22	3-22	2-22
Central	Median	18.5	16.0	17.0
	Range	13-30	5-30	10-30
Posterior	Median	9.0	6.0	8.0
	Range	3-30	3-30	3-30
Sham	Median	8.0	6.0	7.0
	Range	4-15	3-11	4-13

Note—Brackets indicate groups that differ significantly ($p < .05$).

$p < .05$) was found to be significantly correlated with sessions to criterion.

DISCUSSION

The results clearly reveal that rats with relatively small medial thalamic lesions centered on the MD are deficient on acquisition of a food reinforced tone-light go/no-go discrimination relative to animals with either sham operations or anterior thalamic lesions. Animals with lesions primarily involving the habenula and Pf are intermediate between MD-damaged and sham operated rats, not differing significantly from either. Further, the correlation analysis revealed that the acquisition deficit is most highly correlated with MD damage and that only MD and Pf damage correlate significantly with the deficit. The failure of Group C to differ significantly from Group P on two of the criterion measures can be explained in two ways. One, there was considerable overlap in the lesions of these two groups. Two, the MD, upon which the Group C lesion was centered, and the Pf, upon which the Group P lesion was centered, are the two nuclei most highly correlated with the behavioral deficit.

The results of the present study are consistent with studies cited in the introduction indicating that large medial thalamic lesions (Means, Huntley, Anderson, & Harrell, 1973; Vanderwolf, 1971) or lesions confined to either the MD or the CM-Pf produce acquisition deficits. However, it should be noted that in the present appetitive task only the group with the lesion centered on the MD showed a significant deficit, whereas Delacour and his colleagues (1971) have consistently found the CM-Pf complex to be important for importance performance.

The results of the present study and other observations we have made in our laboratory reveal that in the rat relatively little bilateral damage of the medial thalamus is necessary to produce acquisition deficits. This contrasts markedly with the studies done with monkeys, which reveal that the lesions must involve more than 50% MD destruction in order to produce discrimination and delayed response deficits (Chow, 1954; Peters et al., 1956; Schulman, 1964). It would appear that there is a species difference in the relative importance of an intact MD for acquisition.

REFERENCES

- Alexinsky, T., Delacour, J., & Libouban, S. Thalamus et conditionnement défensif: importance relative de trois structures médianes. *Physiology and Behavior*, 1971, 6, 439-446.
- Alexinsky, T., & Houcine, O. CM-Pf complex and alimentary conditioning. *Brain Research*, 1973, 55, 149-158.
- Chow, K. L. Lack of behavioral effects following destruction of some thalamic association nuclei. *Archives of Neurology and Psychiatry*, 1954, 71, 762-771.
- Delacour, J. Effects of medial thalamic lesions in the rat: A review and interpretation. *Neuropsychologia*, 1971, 9, 157-174.
- Delacour, J., Libouban, S., & Martinez, M. P. Effets de lésions thalamiques sur deux types de conditionnement instrumental. *Journal of Physiology*, 1965, 57, 238.
- Delacour, J., & Santacana, M. P. Role du thalamus médian dans le blissement et la rétention de conditionnements défensifs classiques et instrumentaux. *Neuropsychologia*, 1967, 5, 237-252.
- Finger, S., & Frommer, G. P. Effects of cortical and thalamic lesions on temperature discrimination and responsiveness to shock in the rat. *Brain Research*, 1970, 24, 69-89.
- Means, L. W., Harrell, T. H., Mayo, E. S., & Alexander, G. B. Effects of dorsomedial thalamic lesions on spontaneous alternation, maze activity, and runway performance in the rat. *Physiology and Behavior*, 1974, 12, 973-979.
- Means, L. W., Hunt, M. W., Whiteside, R. R., & Bates, T. W. Deficient acquisition and retention of single-alternation go, no-go in rats with medial thalamic lesions. *Physiological Psychology*, 1973, 1, 287-291.
- Means, L. W., Huntley, D. H., Anderson, H. P., & Harrell, T. H. Deficient acquisition and retention of a visual-tactile discrimination task in rats with medial thalamic lesions. *Behavioral Biology*, 1973, 9, 435-450.
- Pellegrino, L. J., & Cushman, A. J. *A stereotaxic atlas of the rat brain*. New York: Appleton-Century-Crofts, 1967.
- Peters, R. H., Rosvold, H. E., & Mirsky, A. F. The effect of thalamic lesions on delayed response type test in the rhesus monkey. *Journal of Comparative Physiology*, 1956, 49, 111-116.
- Schulman, S. Impaired delayed response from thalamic lesions. *Studies in monkeys*. *Archives of Neurology*, 1964, 11, 477-499.
- Tigner, J. C. The effects of dorsomedial thalamic lesions on learning, reversal, and alternation behavior in the rat. *Physiology and Behavior*, 1974, 12, 13-17.
- Vanderwolf, C. H. Limbic-diencephalic mechanisms of voluntary movement. *Psychological Review*, 1971, 78, 83-113.

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