

A comparison of amygdaloid lesion effects in male and female rats

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Amygdaloid lesions decreased the latency of male rats to initiate consumption of a novel food but increased latencies among females. Lesions also depressed the rate of postoperative weight gain of male but not female subjects. Female rats showed shorter latencies on three other ingestional and grooming measures and more rapid acquisition of a passive avoidance task. There were no lesion effects or lesion by sex interactions on these measures. There were also no group differences or interactions in the acquisition of a simple active avoidance task. Further investigations of sex differences in amygdaloid function are suggested.

Recent evidence indicates that the amygdaloid complex is sexually dimorphic in a number of its features. Sex differences in cell body volume of the central and medial amygdala which are abolished by neonatal castration have been noted by Staudt and Dörner (1976). Dimorphism in amygdaloid uptake of methionine in adult mice (MacKinnon, 1973) and puberal rats (Ter Haar & MacKinnon, 1975) and estradiol uptake in neonatal rats (Westley & Salaman, 1977) has also been demonstrated. Baum and Goldfoot (1975) also found that amygdaloid lesions in perpuberal male ferrets reduced blood and testis levels of testosterone and retarded body growth. Such lesions in prepuberal females hastened the onset of first estrous and had no effect on body growth. Raisman (1974) has shown that amygdaloid efferents in the stria terminalis, while not themselves dimorphic, synapse on sexually differentiated neurons within the preoptic area. Kling (1974) has also reported increased aggression in female, but not male, monkeys following amygdaloid lesions. Little attention, however, has been directed toward a systematic comparison of lesion effects on behavior in the two sexes. The present experiment explored this possibility.

METHOD

Subjects

Subjects were 16 male and 16 female rats supplied by the Holtzman Company (Madison, Wisconsin). Male rats weighed 437-515 g and females 250-295 g at the time of surgery. All subjects were of equivalent age. Eight rats of each sex sustained amygdaloid lesions; two received control operations and six sustained scalp incisions. Three female rats (one amygdaloid and two control) died during surgery. Except where noted, rats received ad-lib access to Purina Lab Chow and water throughout the experiment.

Surgery and Histology

Using pentobarbital anesthesia (45 mg/kg), amygdaloid lesions were produced by passing 2.0-mA anodal dc through

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the uninsulated tip of a No. 2 insect pin positioned (skull flat) 2.0 mm posterior to bregma, 4.25 mm lateral to the midline, and 8.25 mm ventral to the cortical surface.

At the conclusion of testing, 24-micron coronal sections were prepared through the lesion area of each experimental rat and stained with thionin.

Procedures

Reactivity to novel foods. Latency to consume a single piece of presweetened cereal (Froot Loops), a small (10 x 10 x 5 mm, ± 2 mm) piece of apple (Washington Delicious), and a single piece of lettuce leaf (approximately 2 cm²) was measured in the home cage. The novel food was placed in a 3.8-cm-diam dish in the rat's cage, and latency to begin and complete consumption of the novel food was recorded by stopwatch. Tests were separated by at least 24 h.

Grooming. Latency to groom in response to a small (approximately 5 cm²) piece of masking tape placed on the dorsal side of the snout, to a length of 1.9-cm-wide masking tape wrapped around the tip of the tail, and to a small quantity of Vaseline smeared on the mystacial vibrissae was next measured. For each test the stimulus was applied, the animal replaced in its cage, and the latency to begin removing the offending stimulus measured by stopwatch. Tests were separated by 24 h.

Latency to eat or drink when deprived. Latency to begin consumption of a small (6.1 to 6.4-g) piece of Purina Lab Chow when 24-h food deprived or to begin drinking from a water bottle when 24-h water deprived was next measured by stopwatch. These tests were separated by 72 h.

Passive avoidance. Five days after the completion of home cage testing, the rats were tested in a step-down avoidance task. The apparatus and test procedures have been described in an earlier publication (Nagel & Kemble, 1976). Briefly, rats were placed on a small wooden platform above a grid floor and punished with 1.0-mA scrambled footshock on two consecutive trials when they stepped to the floor. The third step-down response was unpunished. Step-down latencies (up to 600 sec) were recorded for all three step-down responses.

Active avoidance. Five days after passive avoidance testing, the rats were tested on a simple jump-up avoidance task. The apparatus and test procedures were described in an earlier publication (Kemble & Strand, 1977). Briefly, the rats were tested in a Lafayette (Model 85250) automated avoidance system. The rats were adapted to the apparatus for 5 min on 2 consecutive days. Number of rears was recorded during apparatus adaptation. On the third day each subject received 25 training trials. At the beginning of each trial a retracting wall exposed a small stainless steel platform. If the rat failed to jump to the platform within 10 sec, it was punished by

(up to) 5 sec of neon scrambled .5-mA footshock. The rat was permitted to rest on the platform for 30 sec and was then returned to the grid floor by the retracting wall for a 40-sec intertrial interval.

RESULTS

Histological

Experimental subjects sustained damage to the ventral portions of the basolateral and corticomедial amygdala, nucleus of the lateral olfactory tract and pyriform cortex. The posterior portions of the amygdala were spared in all animals. Unilateral or (rarely) bilateral damage to the caudate-putamen, globus pallidus, or internal capsule was noted in some rats but did not discernibly affect the observations. Although lesion size and placement varied somewhat, there were no systematic differences in the lesions of male and female rats. Representative lesions from a male and female subject are reconstructed in Figure 1.

Body Weight

Body weights increased steadily following surgical treatment and exceeded preoperative levels at the beginning of behavioral testing (male amygdaloid, mean = 509 g; male control, mean = 542 g; female amygdaloid, mean = 296 g; female control, mean = 292 g). Male rats with lesions, however, remained consistently lighter than their control subjects throughout the experiment ($p < .01$). There were no group differences among females after 15 days of recovery or thereafter ($p > .10$).

Ingestion and Grooming

Latencies to begin consummatory or grooming behavior are summarized in Table 1. The latencies were compared by analysis of variance for each measure. On the first consummatory measure (Froot Loops), it can be seen that amygdaloid lesions decreased consumma-

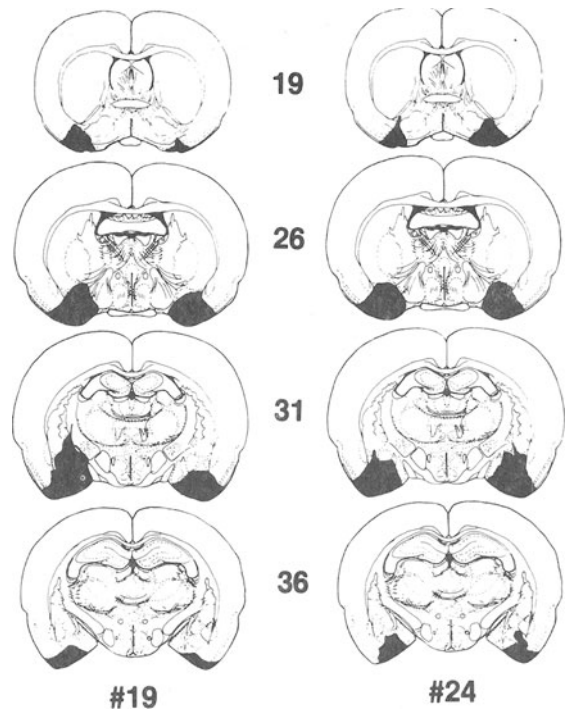


Figure 1. Reconstruction of a representative amygdaloid lesion in a male (Subject 19) and female (Subject 24) rat on plates redrawn from the atlas of König and Klippel (1963). Plate numbers are indicated in the center column.

tory latencies among male rats but increased latencies among female rats [$F(1,25) = 4.27$, $p < .05$]. Female rats were slower to begin consumption of lettuce and to begin removal of tape applied to the tail but began water consumption more quickly when deprived [$F_s(1,25) = 4.32-7.63$, $ps < .05$]. There were no further lesion or sex effects or lesion by sex interactions ($ps > .10$). There were no group differences or interactions in time to complete consumption on the ingestional or grooming measures.

Table 1
Mean Latencies (Seconds) and Ranges to Initiate Consumption of Novel Foods, Grooming, or Food or Water Consumption (Deprived)

	Novel Foods			Grooming			Deprived	
	Froot Loops	Apple	Lettuce	Nose	Tail	Vibrissae	Food	Water
Male Amygdaloid								
Mean	79.8	55.9	48.2	28.6	65.2	42.1	31.9	74.4
Range	25-126	14-116	12-91	5-79	17-207	10-97	17-61	1-416
Male Control								
Mean	210.6	33.1	50.1	73.9	48.6	31.6	37.8	51.4
Range	23-600	8-72	7-122	14-213	7-168	6-103	20-123	1-313
Female Amygdaloid								
Mean	249.7	42.3	85.1	91.1	166.0	59.6	50.7	9.7
Range	18-600	9-102	17-216	8-420	26-459	5-141	12-113	2-32
Female Control								
Mean	99.7	314.3	235.0	119.8	234.8	39.2	20.7	5.3
Range	21-175	5-1800	10-600	20-278	24-658	8-73	7-41	1-15
Statistical Summary	Lesion by Sex*	n.s.	Sex*	n.s.	Sex*	n.s.	n.s.	Sex*

Note—n.s. indicates $p > .10$ for all comparisons. * $p < .05$.

Passive Avoidance

There were no group differences in initial step-down latencies (means = .64-9.88 sec). Following the first punished step-down, female rats (mean = 19.32 sec) were slower to step down than males [mean = 6.54 sec, $F(1,25) = 5.02$, $p < .05$]. Significant group differences (male, mean = 28.50 sec; female, mean = 166.48 sec) in step-down latency were also observed after the second footshock [$F(1,25) = 4.46$, $p < .05$]. There were no lesion effects or lesion by sex interactions on step-down latencies.

Active Avoidance

During the first adaptation period, rats with amygdaloid lesions (male, mean = 27.4; female, mean = 32.3) reared somewhat more frequently than control rats [male, mean = 19.1; female, mean = 25.3, $F(1,25) = 4.14$, $.05 < p < .10$]. This difference disappeared during the second adaptation period ($p > .10$). There were no sex differences or lesion by sex interactions during either period ($ps > .10$). The avoidance task was acquired rapidly by all groups (means = 19.3-20.8 avoidances/25 trials), with no suggestion of lesion or sex effects or lesion by sex interaction ($ps > .10$). Similarly, response latencies declined rapidly (means = 2.3-4.6 sec on Trial 5), with no suggestion of lesion or sex effects or lesion by sex interaction ($ps > .10$).

DISCUSSION

The present results suggest that sex differences in the behavioral effects of amygdaloid lesions may be restricted to reactivity to novel foods and, perhaps, body weight recovery. The lesion-induced reduction in latency to consume Froot Loops among males is similar to the reduced taste neophobia reported by Nachman and Ashe (1974) and contrasts sharply with the increased latencies noted among experimental females. Although these effects were not seen on the remaining two foods, previous research in our laboratory (Kemble, Levine, Gregoire, Koepp, & Thomas, 1972) suggest that amygdaloid lesion effects on taste reactivity may be obscured by repeated testing. The postoperative depression of weight gain by male, but not female, subjects is also similar to that reported in prepubertal ferrets by Baum and Goldfoot (1975). This finding is complicated by the considerable sex differences in preoperative body weight, however. In our experience, recovery of preoperative weight is considerably slower among heavier males. It is possible, of course, that lesion effects or lesion by sex interactions on the remaining ingestion and grooming tests were obscured by the considerable variability in latencies. It should be remembered, however, that significant sex differences were found on three of these tests.

Although clear sex differences emerged in the passive avoidance task, the absence of lesion effects or lesion by sex interactions is puzzling. In a previous experiment (Nagel & Kemble, 1976) employing the same apparatus and similar procedures, amygdaloid lesions produced a clear acquisition impairment in male rats. It may be that the initial ingestion and grooming tests obscured lesion effects on this task. The lesions in this experiment were also slightly more anterior than those previously reported.

It is clear that neither lesions nor sex had detectable effects on acquisition of the simple active avoidance task used here. In previous research employing male rats, we have repeatedly failed to note amygdaloid lesion effects on simple active avoidance tasks (Kemble & Tapp, 1968; Kemble, Note 1). Since

two-way avoidance acquisition is enhanced in female rats following some small amygdaloid lesions (Grossman, Grossman, & Walsh, 1975), it is possible that sex by lesion interactions would emerge in a more complex task.

Although the present data suggest only limited lesion by sex interaction in the amygdala, two qualifications should be made. First, it is possible that two or more functionally distinct, and perhaps antagonistic, systems were destroyed by the large lesions employed in this experiment. Since functional heterogeneity of the amygdala is well documented (e.g., Grossman et al., 1975), smaller lesions may be essential. Second, the behavioral tasks chosen may not have been optimal for the detection of lesion by sex interactions. Two obvious candidates are the choice of passive and active avoidance tasks. Further research employing both smaller lesions and a modified test battery are in progress.

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1. Kemble, E. D. *Effect of amygdaloid lesions on active avoidance acquisition*. Unpublished observations.

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