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Sexual Behavior in Male Rats After Radiofrequency or Dopamine-Depleting Lesions in Nucleus Accumbens

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LIU, Y.-C., B. D. SACHS AND J. D. SALAMONE. *Sexual behavior in male rats after radiofrequency or dopamine-depleting lesions in nucleus accumbens.* PHARMACOL BIOCHEM BEHAV **60**(2) 585–592, 1998.—Considerable neurochemical evidence links dopamine (DA) in nucleus accumbens (NAcc) to male sexual behavior. The present experiments were conducted to extend this information to the male's sexual response to remote stimuli from estrous female (noncontact erection; NCE). Male rats were tested for copulation and NCE after either 6-hydroxydopamine (6-OHDA) or radiofrequency (RF) lesions in NAcc). Males with an average 78% depletion of DA in NAcc had a lower incidence of NCE, longer latency to display NCE, and fewer erections. DA-depleted males also had less locomotor activity after injections of *d*-amphetamine, and reductions in apomorphine-induced yawning, but a normal incidence of penile erection. Males with RF lesions of the NAcc had longer NCE latencies. All males copulated to ejaculation after either 6-OHDA or RF lesions with little or no deficit, although the 6-OHDA–treated males had longer intromission latencies. The NCE deficit supports the hypothesized role of NAcc DA in arousal processes in responding to remote cues from estrous females. The minimal effect of lesions on copulation suggests that the presence of additional proximal stimulation during copulation may overcome the deficits induced by DA depletions or lesions in NAcc. © 1998 Elsevier Science Inc.

Nucleus accumbens Dopamine Noncontact erection Copulation Sexual arousal Male rats

NEUROCHEMICAL and lesion studies have yielded conflicting evidence about the role of dopamine (DA) in nucleus accumbens (NAcc) in male sexual behavior. Microdialysis studies have demonstrated that extracellular DA is increased when male rats are exposed to inaccessible estrous females (6,29), and remains elevated during copulatory behavior and until ejaculation (6,32,44). DA-related voltammetric signals increase during sexual behavior (19,21,31) and with the presentation of novel odors associated with estrous females (45). Yet despite the evidence indicating that accumbens DA release is associated with aspects of male sexual behavior, the precise role of DA in sexual behavior remains unclear. Recent voltammetric evidence indicates that DA-related signals increase in response to chasing, mounting, and intromission (22). Yet these markers of extracellular DA actually decrease with ejaculation (22), suggesting that accumbens DA release does not mediate the hedonic aspects of ejaculation. In addition, evidence from studies employing cell body or DA-depleting lesions of the NAcc indicates that damage to this brain area has little or no effect upon male sexual behavior. Depletions of accumbens DA by local injections of the neurotoxic agent, 6-hydroxydopamine (6-OHDA), delayed the initiation of copulation in male rats (9,33), but did not change the number of mounts or intromissions, nor did they alter the intromission ratio, a common index of erectile function in copula (9). Neither electrolytic lesions (2) nor blockade of DA receptors in accumbens by local injections of haloperidol (30) caused more than minor impairment of copulatory behavior. Injections of apomorphine into the ventral tegmental area to decrease DA neuron activity resulted in motor slowing, but did not alter the selection of estrous females by male rats in an X-maze procedure (15). Thus, despite the neurochemical changes seen in NAcc that are associated with male sexual behavior, pharmacological or neurotoxic disruption of

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accumbens DA, as well as lesions of the intrinsic cell bodies of this structure, leave fundamental aspects of sexual behavior and motivation intact.

Of course, it remains possible that aspects of sexual behavior that are not usually assessed in standard tests of copulation would be affected by accumbens DA depletions. For example, responding on a higher order schedule for sexual reinforcement was affected by accumbens DA depletions (9). This is consistent with other data indicating that accumbens DA is involved in responsiveness to conditioned stimuli or remote cues (3,9,33,39,40,42). Recently, procedures have been developed for the assessment of noncontact erections (NCEs) (38). NCEs, which occur in response to remote cues from estrous females, are thought to be related to the autonomic arousal that is characteristic of sexual responsiveness (34,35). NCEs are analogous to human psychogenic erections, usually defined as erections initiated by brain centers in response to visual, auditory, chemosensory, or imaginative stimuli (23,34,35). Previous research has indicated that brain structures involved in NCEs can be dissociated from those that mediate copulatory behavior. In rats, excitotoxic or radiofrequency lesions of the medial preoptic area substantially impaired copulatory behavior, but did not alter NCEs (18). Conversely, radiofrequency lesions of the medial amygdala (17) or bed nucleus of the stria terminalis (18) severely impaired NCEs, but they caused only moderate impairment of copulation. Thus, it is possible that manipulations of the NAcc could alter NCEs, despite the fact that these same conditions would have little effect upon copulatory behavior.

The present experiments were conducted to explore the role of the NAcc in mediating NCE in male rats. We examined the effects of 6-OHDA depletion of DA in the NAcc on NCE and copulatory behavior. In a separate experiment, we also studied the behavioral effects of radiofrequency lesions in the NAcc. Males with 6-OHDA lesions were also tested for apomorphine-induced penile erection and yawning, and for *d*-amphetamine–induced locomotor activity.

GENERAL METHOD

Animals

A total of 52 Long–Evans rats of Blue Spruce origin (Harlan–Sprague–Dawley, Indianapolis, IN) were 80–90 days of age at the beginning of these experiments. Upon arrival in the laboratory, males and females were housed in separate rooms in groups of three to four in wire-mesh cages (43 × 34 × 21 cm). Commercial rodent chow and tap water were freely available. The colony room temperature was maintained at 23 ± 1°C, and lights in the 12 L:12 D cycle went off at 1100 h. All behavioral tests were conducted between 1300 and 1800 h. Female rats were given estradiol benzoate (50 μg/rat, SC) and progesterone (500 μg/rat, SC) 48 h and 4–6 h, respectively, prior to being used as stimuli in tests of male's sexual responses in all experiments.

Prior to experimental use, all males were given three tests for copulation and two tests for NCE as described below. Males were used in these studies only if they copulated to ejaculation and had at least one NCE in the last screening test.

Behavioral Tests

NCE. NCE tests (38) were conducted in a clear Plexiglas chamber (50 × 24 × 30 cm), which was divided in half by three partitions placed 1 cm apart. The center partition had four equally spaced "windows" (2.5 × 9 cm); the other partitions had four equally spaced "doors" (2.5 × 7.5 cm) aligned below the windows. Thus, the chamber prevented direct contact between the animals, but allowed reciprocal auditory, visual, and olfactory communication. The test chambers were littered with wood chips (Sanichips). Male rats were individually placed in one side of the chamber and given 5 min for acclimation. The test was started by putting a receptive female into the other side. A video camera was placed in the test room, and behavior was observed on a monitor in another room. Erections were scored when the penis emerged from the penile sheath, or when genital grooming was accompanied by hip flexion or elevation of the heels of the hindfeet, acts reliably associated with erection (36,38). The latency to first erection and the number of erections were entered into a computer (13) and counted. The number of nose pokes by the male through the "doors" was recorded as a measure of the male's attention to the female. The NCE test was terminated 15 min after the first erection, or 20 min after introducing the female if no erection occurred.

Copulation. Copulatory behavior was tested in a glass aquarium (50 × 27 × 30 cm) with Sanichips on the floor. A male was given 5 min to acclimate to the test chamber, after which a receptive female was introduced and the test was begun. The test was terminated after the first ejaculation, or 30 min after the first intromission if no ejaculation occurred, or 30 min after introduction of the female if there was no intromission. Occurrences of mounts without intromission, mounts with intromission, and ejaculation were entered into a computer (13) and counted. Additional measures derived from the event records were: latency to first mount, latency to first intromission, ejaculation latency (timed from first intromission), intromission ratio (intromissions divided by the sum of mounts and intromissions).

Apomorphine-induced erection and yawning. In the 6-OHDA experiment, each male was put in a clear Plexiglas chamber (28 × 28 × 21 cm) immediately after injection of apomorphine (0.06 mg/kg, SC; Sigma, St. Louis, MO), and the number of penile erections and yawns were recorded for 45 min. The motor pattern of apomorphine-induced erection appears to be indistinguishable from that of NCE (34,35,38).

d-*Amphetamine–induced locomotion. S*ystemic injection of *d*-amphetamine can increase locomotion in rats, and this effect is suppressed after depletion of DA in the NAcc (16). Therefore, in the 6-OHDA study, the males were also tested for locomotion after injection of d-amphetamine (2.0 mg/kg, IP; Sigma, St. Louis, MO) to verify the behavioral effects of the depletion of DA in NAcc. The locomotion test (90 min) was performed in clear Plexiglas activity chambers (28 × 28 × 21 cm). Two movable wire mesh floor panels were mounted on a central rod, and movements of the rat on the floor were detected by microswitches attached on the panels. Each microswitch closure was counted as a single activity count.

Neurochemical Analysis for DA

After completion of all behavior tests in the 6-OHDA experiment, rats were exposed to CO_2 for 30 s and then decapitated. The brains were removed and frozen. Bilateral NAcc samples were dissected out from a 0.75 mm-thick coronal section with a 16-ga stainless steel tube. Another bilateral tissue sample was collected from caudate putamen in the same coronal section to serve as a control site. The tissue samples were placed in 200 μl of chilled 0.1 N perchloric acid, homogenized, and centrifuged (14,000 RPM, 4 min), and the supernatant (10 μl for each sample) was used for neurochemical analysis.

These analyses (5) were conducted by a high-performance liquid chromatography (HPLC) system, which consisted of a Waters dual-piston pump, a precolumn filter, a reverse-phase column, a Coulochem electrochemical detector, and a chart recorder. The mobile phase was a pH 4.5 phosphate buffer that also contained 7.0% methanol, EDTA, and 2.6 ml of 0.4 M sodium octyl sulphate. The oxidation potential used for these analyses was 0.2 V (vs. reference electrode). Standard of DA (Sigma, St. Louis, MO) were assayed at the same time as the samples.

Histology

In the RF lesion experiment, after completion of all behavioral tests, males were deeply anesthetized and perfused intracardially with 0.9% saline followed by 10% formalin. Brains were removed and stored in 10% formalin. Frozen sections were cut at 50 μm in the coronal plane through the target regions, and stained with cresyl violet. The atlas of Paxinos and Watson (28) was used to analyze and depict the lesions.

Statistical Analysis

Because of the low incidence of response in some NCE tests and in the test for apomorphine-induced penile erection and yawning, nonparametric tests were used to compare treatment effects for these measures. Proportional data were analyzed by comparing lesion groups with sham operated groups using the Fisher exact probability test. Latency data were evaluated by survival analyses (i.e., Kaplan-Meier statistics). The number of responses are reported as medians and analyzed by Mann–Whitney tests. Because all rats displayed nose pokes in both NCE tests, copulated to ejaculation in copulation tests, and had locomotor activity in the locomotion test, these data and the results of neurochemical analysis are reported in means ± SEM, and groups were compared by *t*-tests. SPSS software (Chicago, IL) were used for all statistical analysis, and significance was inferred when $p < 0.05$.

Brain Treatments and Testing Schedules

6-OHDA injections into the NAcc. Twenty-six male rats were randomly divided into a NAcc-depletion group (NAccd, $n = 16$) and a vehicle control group (vehicle, $n = 10$). After anesthetization with sodium pentobarbital (60 mg/kg, IP) each rat was placed in a stereotaxic apparatus that had the incisor bar set at 3.3 mm below the interaural line. The stereotaxic coordinates for the NAcc lesions relative to bregma were AP +1.9 mm, ML ± 1.5 mm, DV −6.6 mm from surface of the brain (27). After a midline incision (15–20 mm), two burr holes were made on each side of the skull; then a 30-ga. injector was lowered to the NAcc region on one side, then the other. The 6-OHDA (12.5 μg of the free base of 6-OHDA in 2.5 0.0%l of 0.1% ascorbic acid per side; RBI, Natick, MA) was injected at a rate of 0.5 μl/min through the injection tip with PE-10 tube linked to a 10 μl Hamilton syringe operated by a Harvard 22 microprocessor syringe pump (Harvard Apparatus, South Natick, MA). The injector was left in place 2 min after each injection. For vehicle controls, the same volume of 0.1% ascorbic acid was injected into the NAcc regions. The incision was closed with 11-mm wound clips. In addition, each male was given pargyline (20 mg/kg, IP; Sigma, St. Louis, MO), a monoamine oxidase inhibitor, 30 min before 6-OHDA or vehicle injection. Males were given an NCE test (NCE test 1) 6–8 days after surgery, followed 1–2 days later by a copulation test. Each male was retested for NCE (NCE Test 2) 4–5 days after the copulation test. The test for apomorphine-induced penile erection and yawning, and for locomotion, followed at 6–7-day intervals.

RF lesion of the NAcc. In this study we used radiofrequency lesion through a RFG-4A lesion maker and TCZ electrodes (Radionics Inc., Burlington, MA), which destroyed both neurons and fibers of passage. Each male was placed on a stereotaxic apparatus after anesthesia, and the setting of stereotaxic coordinates was the same as in the 6-OHDA experiment. The surgical procedure was similar to the 6-OHDA injection, and the RF electrode (tip diameter 0.25 mm, tip exposure 0.25 mm) was lowered to the NAcc region through a burr hole on one side, then the other side. Tip temperature was set at 78°C for 90 s for NAcc lesions (NAccx, $n = 16$). For males with sham surgeries (sham, $n = 10$), the electrode was lowered to 1.0 mm above the target regions, and no heat was generated. The incision was closed with 11-mm wound clips. Six to 8 days after surgery, males were tested for NCE (NCE test 1), followed 1–2 days later by a copulatory test (copulation test). Then 4–5 days after the copulation test, each male was given another NCE test (NCE test 2).

RESULTS

6-OHDA Dopamine-Depletion in the Nucleus Accumbens (NAccd)

After neurochemical analysis, 11 6-OHDA-treated males that had more than 67% depletion of DA levels in the NAcc (compared with the mean of the vehicle control males) were included in the data analysis. Thus, depleted males had significantly lower DA levels in the NAcc than the vehicle control males [Table 1, >78% depletion; $t(19) = 9.88$, $p = 0.0001$], but not in the caudate putamen (NS). The results of the locomotor activity test also showed the typical effect of 6-OHDA treatment of accumbens (Table 1), in that the DA-depleted males had a significantly reduced locomotor response to *d*-amphetamine than the vehicle control males, $t(19) = 3.43$, $p = 0.003$.

Relative to vehicle controls, the incidence of NCE (Fig. 1) was lower for the NAccd males in both postoperative tests, but reliable only for test 2 ($p = 0.009$). The NCE latency was longer in NAccd males than in vehicle controls in both tests (Fig. 2; NCE test 1, log rank = 4.51, $df = 1$, $p = 0.03$; NCE test 2, log rank = 8.56, $df = 1$, $p = 0.003$). The NAccd males also had fewer erections in both tests, but this effect was significant only for test 2 (Table 2; $Z = -2.37$, $p = 0.02$). The number of nose pokes was not significantly different between the two groups (Table 2). In the postoperative copulatory test (Table 3, copulation test), all males copulated to ejaculation. The NAccd males had a longer intromission latency than the

TABLE 1

DOPAMINE LEVELS AND *d*-AMPHETAMINE-INDUCED LOCOMOTOR ACTIVITY AFTER 6-OHDA INJECTION IN THE NUCLEUS ACCUMBENS

	DA (ng/mg Wet Tissue)		
	NAcc	CPu	Locomotion (90)
Vehicle (n =	3.42 ± 0.27	4.14 ± 0.26	1144 ± 110
NAccd (n =		4.05 ± 0.31	747 ± 48*

Values are mean ± SEM.

*$p < 0.01$, *t*-test, compared with vehicle group. NAcc = nucleus accumbens; CPu = caudate putamen.

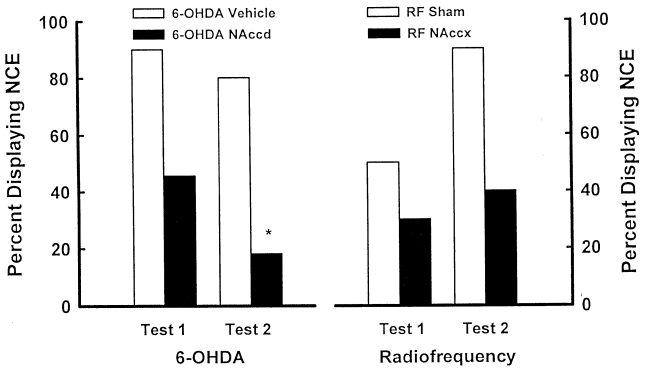

FIG. 1. Incidence of noncontact erection (NCE) after 6-OHDA injection (6-OHDA, $n = 11$; vehicle, $n = 10$) or RF lesions (lesions, $n = 16$; sham, $n = 10$) in NAcc. Males with 6-OHDA DA depletion were impaired relative to vehicle controls in NCE test 2. *$p < 0.01$, Fisher Exact Probability test.

vehicle control males, $t(19) = 2.58$, $p = 0.018$, but there was no reliable difference between the two groups in other measures of copulation (Table 3). Finally, in the test for apomorphine-induced penile erection and yawning, the groups did not differ significantly in the incidence (Table 4) or latency (Fig. 3) of erections, but the NAccd males had a marginal reduction in the number of erections (Table 4; $Z = -1{,}89$, $p = 0.058$). Yawning was exhibited by a lower proportion of NAccd males (Table 4; $p = 0.02$), and they had a longer latency (Fig. 3; log rank = 10.07, $df = 1$, $p = 0.0015$), and fewer yawns (Table 4; $Z = -2.74$, $p = 0.006$) than vehicle control males.

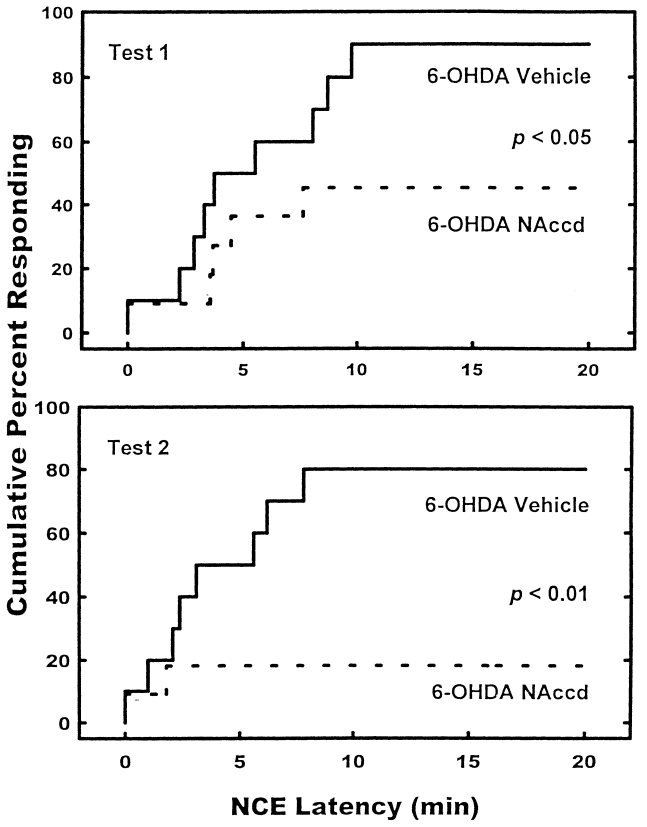

FIG. 2. NCE latencies of males after 6-OHDA DA depletion (NAccd, $n = 11$) or vehicle injection (vehicle, $n = 10$) in NAcc. Difference between groups tested by Kaplan-Meier survival statistics.

TABLE 2

NUMBERS OF NCEs AND NOSE POKES AFTER TREATMENT WITH 6-OHDA OR RF LESIONS IN THE NUCLEUS ACCUMBENS

		Number of NCEs*		Number of Nose Pokes†	
		Test 1	Test 2	Test 1	Test2
6-OHDA	Vehicle	2.0	1.5	49.8 ± 3.6	71.9 ± 4.9
	NAccd	0.0	0.0‡	49.7 ± 6.3	73.7 ± 8.4
RF	Sham	0.5	2.0	49.1 ± 6.2	63.4 ± 7.5
	NAccx	0.0	0.0	54.3 ± 7.5	72.3 ± 9.8

*Values are median.
†Values are mean ± SEM.
‡$p < 0.05$, Mann–Whitney test, compared with vehicle group. In 6-OHDA experiment: NAccd, $n = 11$; vehicle, $n = 10$. In RF experiment: NAccx, $n = 10$; sham, $n = 10$.

RF Lesions of the NAcc

Histology revealed bilateral lesions in ten NAccx males, primarily in the medial portion of the core and the lateral portion of the shell. In most cases the anterior part of the anterior commissure was also partially damaged (Fig. 4).

There were no significant differences between NAccx and Sham males in the proportion displaying NCE in either postoperative test (Fig. 1). The number of erections and nose pokes were also not significantly different between groups in either test (Table 2). However, NAccx males had longer NCE latencies in both tests (Fig. 5) than sham males, but the difference was reliable only in test 2 (log rank = 5.81, $df = 1$, $p = 0.016$). All males reached ejaculation in the copulation test, and there were no significant differences between the groups on any measure (Table 3).

DISCUSSION

In these experiments, cell body or DA-depleting lesions of the NAcc significantly impaired NCE behavior. After accumbens DA depletions, the NAccd males had significantly longer latencies to the first erection in both NCE tests compared to vehicle-control males (Fig. 2). The incidence of NAccd males displaying NCE (Fig. 1) and the number of erections (Table 2) tended to be smaller than vehicle controls in both tests, but were significant only in test 2. Males with RF lesions of NAcc had the same trend as 6-OHDA–treated males for the incidence of displaying NCE (Fig. 1), NCE latencies (Fig. 4), and the number of erections (Table 2) in both tests, but group differences were reliable only for NCE latency in test 2. The significantly longer latency to first NCE (three of four tests across experiments) and the modest reduction in number of NCEs (one of four tests across experiments) in males with NAcc lesions or DA depletions suggests that NAcc is a part of the neural circuitry that regulates the display of NCEs. These results support the view that the NAcc participates in sexual arousal processes (9,14,30,44).

TABLE 3

MEASURES OF COPULATORY BEHAVIOR AFTER 6-OHDA INJECTION OR RF LESIONS IN THE NUCLEUS ACCUBENS

		IR	No. Mounts	No. Intros.	ML (min)	IL (min)	III (min)	EL (min)	PEI (min)
6-OHDA	Vehicle	0.76 ± 0.05	4.1 ± 1.3	9.9 ± 1.2	0.14 ± 0.03	0.18 ± 0.04	0.74 ± 0.14	7.27 ± 1.66	7.14 ± 0.40
	NAccd	0.75 ± 0.04	3.9 ± 1.0	9.6 ± 0.9	0.20 ± 0.04	0.56 ± 0.13	0.60 ± 0.07 *	6.03 ± 1.04	7.59 ± 0.23
RF	Sham	0.70 ± 0.05	4.9 ± 1.1	10.0 ± 1.4	0.22 ± 0.06	0.27 ± 0.06	0.49 ± 0.04	4.88 ± 0.84	6.47 ± 0.14
	NAccx	0.67 ± 0.05	5.6 ± 1.3	9.8 ± 0.9	0.17 ± 0.03	0.83 ± 0.33	0.62 ± 0.01	6.01 ± 1.07	6.85 ± 0.42

Values are mean ± SEM.

*$p < 0.02$, *t*-test, compared with vehicle group. In 6-OHDA experiment: NAccd, $n = 11$; vehicle, $n = 10$. In RF experiment: NAccx, $n = 10$; sham, $n = 10$. IR = intromission ratio; No. mounts = number of mounts; No. Intros. = number of intromissions; ML = latency to first mount; IL = latency to first intromission; III = interintromission interval; EL = ejaculation latency; PEI = postejaculatory interval.

Previous work has shown that olfactory cues are essential for evoking NCE (8,37), and lesions of medial amygdala eliminate this sexual response (17). The NAcc receives olfactory input, particularly through projections from the medial amygdala to the shell part of the accumbens (4,12,46). It has been suggested that the NAcc is a "limbic-motor interface" for translating sensory and emotional processes into motor output (25), and that dopaminergic modulation of the activity of neurons in accumbens could serve a "gating" function to influence output (40,41). In addition, DA in NAcc has been implicated in the modulation of behavioral responsiveness to conditioned or remote incentive stimuli (9,33,39,40,42). Thus, in view of the fact that NCE tests measure behavioral responses to remote cues from inaccessible estrous females (38), the results obtained from the present studies are consistent with previous hypotheses of NAcc function. However, the present results are unique in that the response being disrupted by interference with NAcc is not a skeletal motor response such as locomotion or lever pressing, but apparently includes an autonomically mediated response, i.e., penile erection. This inference should be tested by direct measures of erection, rather than the indirect ones used in these studies, because of the possibility that disruption of NAcc function interfered only with the motor component of NCE.

In the 6-OHDA experiment, DA in NAcc was depleted by 78% in 6-OHDA–treated males relative to vehicle-treated rats. These depletions were substantial enough to affect NCE and reduce amphetamine-induced locomotion, although 6-OHDA treatment had little effect on several aspects of copulatory behavior. Despite the fact that the intromission latencies of NAccd males were longer than vehicle-injected males, experimental and control males were similar on all other measures of copulatory behavior in the 6-OHDA experiment, as well as in the RF lesion study. In particular, it should be emphasized that the lesion and control groups in both experiments had similar intromission ratios, suggesting that NAcc lesions did not impair erectile function during copulation. The relative preservation of copulatory function after NAcc lesions or DA

TABLE 4

INCIDENCE AND NUMBER OF ERECTIONS AND YAWNING AFTER APOMORPHINE INJECTION IN 6-OHDA- AND VEHICLE-TREATED MALES

	Penile Erection		Yawning	
	Proportion	No. Erection*	Proportion	No. Yawning*
Vehicle	8/10	2.0	9/10	2.5
NAccd	6/11	1.0	4/11†	0.0‡

*Values are median.

†$p < 0.05$, Fisher exact probability test. ‡$p < 0.01$, Mann–Whitney test, compared with vehicle group. 6-OHDA lesion; NAccd, $n = 11$; Vehicle, $n = 10$.

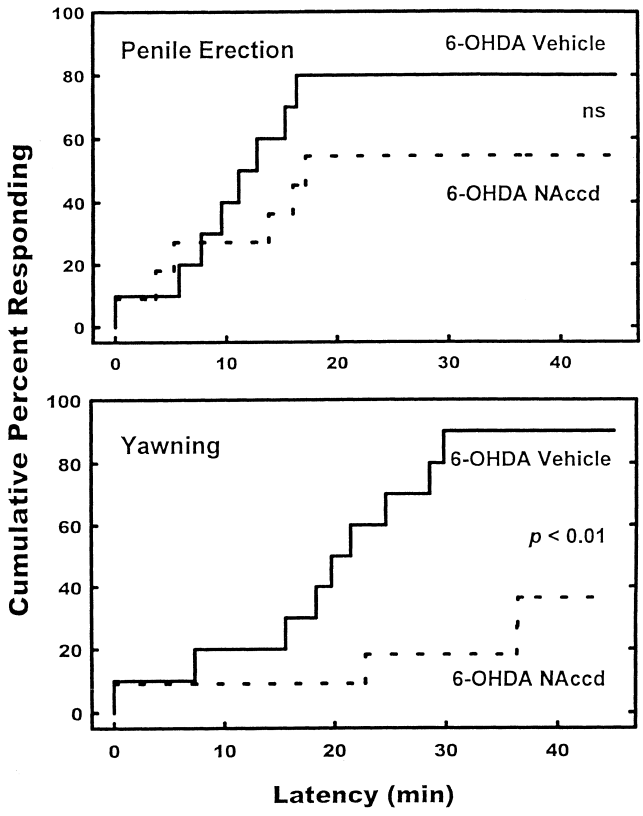

FIG. 3. Latencies for penile erection and yawning after apomorphine injection in males previously treated with 6-OHDA ($n = 11$) or vehicle ($n = 10$) in NAcc. Difference between groups tested by Kaplan-Meier survival statistics.

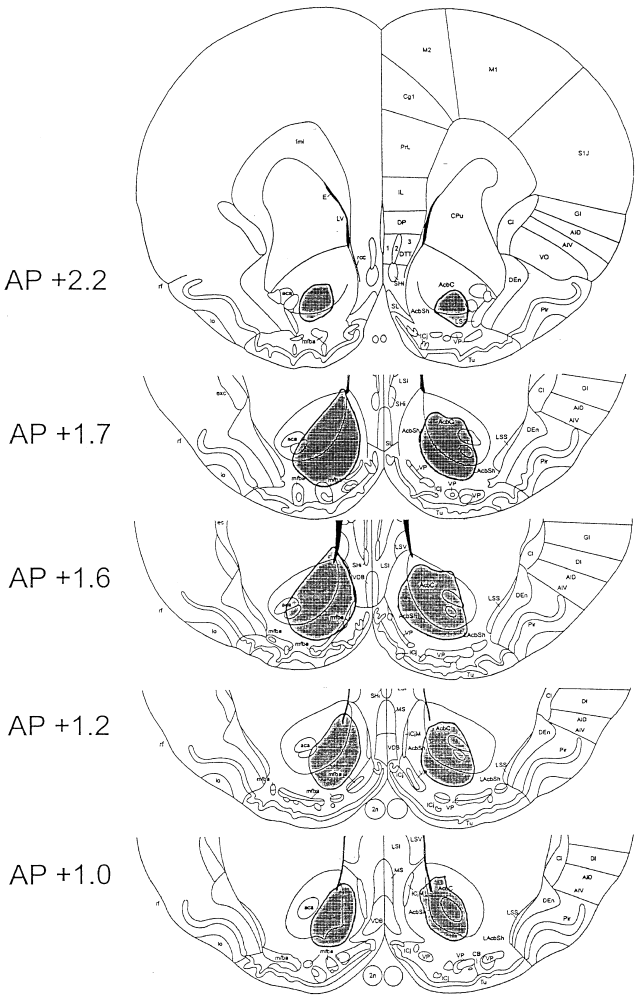

FIG. 4. Median perimeter of RF lesions in NAcc, mapped on atlas of Paxinos and Watson (28).

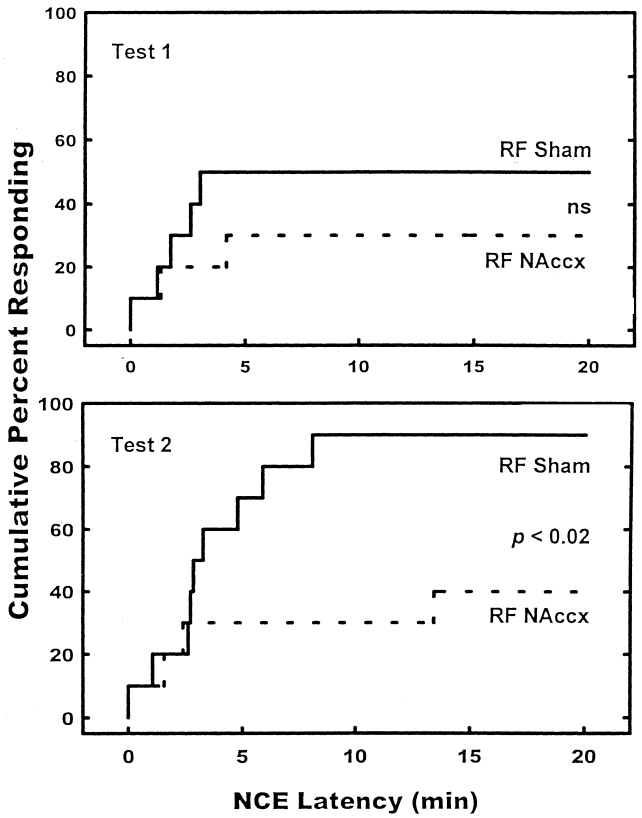

FIG. 5. NCE latencies of males after RF lesions (NAccx, $n = 16$) or sham operation (sham, $n = 10$) in NAcc. Difference between groups tested by Kaplan-Meier survival statistics.

depletions is generally consistent with previous studies, reviewed above, using various techniques to impair NAcc function (2,30,33). In addition, the lack of effect on nose pokes after cell body or DA-depleting lesions suggests that any deficit in NCE was not due to reduced attention to the female. Thus, despite the fact that cell body or DA-depleting lesions of NAcc disrupted NCE, several other aspects of sexual behavior were left intact after these manipulations. Clearly, it would be an oversimplification to state that accumbens DA depletions or lesions impaired "motivation," "reward," "preparatory behavior," or even "erections," without further qualification; the deficits in erectile function produced by lesions or DA depletions of accumbens were highly context specific.

There are many reports that extracellular DA levels in the NAcc increase during copulation until ejaculation (6,10,21,29, 32,44). However, depleting accumbens DA had relatively little effect on copulatory behavior [(33) and present article]. Previous reports have indicated that the response-suppressing effects of interference with DA function can be overridden by increasing the sensory input (40). For example, changing environmental stimulation reversed the decline in locomotion induced by treating rats with haloperidol (20). In the present experiments, the proximal stimuli from the female during the copulation tests may have overcome the lesion-induced deficit that was manifest in the NCE tests, in which only remote cues from the female were available to the male.

Systemic administration of low doses of the DA agonist, apomorphine, can induce penile erection and yawning in rats (11,24,26). This effect can be blocked by pretreatment with the DA antagonist, haloperidol (11,43). Several previous studies indicated that the behavioral effects of systemic apomorphine treatment are mediated by multiple sites within the brain. For example, electrolytic lesion of the paraventricular hypothalamus (PVH) abolished apomorphine-induced erections and yawning (1). Depletions of striatal DA by injections of 6-OHDA into caudate putamen also abolished apomorphine-induced erections and yawning (7). Microinjection of apomorphine (1 g) into PVH induced both penile erection and yawning, but similar injections into NAcc were ineffective (24). Our data suggest that NAcc DA does play a role in apomorphine-induced yawning, but little or no role in apomorphine-induced penile erection. It is possible that accumbens DA depletions reduced the effect of apomorphine on yawning because the DA depletions resulted in DA receptor supersensitivity, which eliminated the yawning effect of apomorphine that normally occurs at a relatively low dose. In addition, the lack of effect of DA depletions on apomorphine-induced penile erections suggests that erections induced by remote cues

from females and those induced by apomorphine are regulated by different brain mechanisms.

In summary, male rats with depletions of accumbens DA had deficits in NCE, which supports the hypothesized role of NAcc DA in sexual arousal processes involved in responding to remote cues from estrous females. After incurring cell body or DA-depleting lesions of NAcc, these males had little or no deficit in nose pokes or copulatory behavior. We therefore infer that the deficit in NCE was not due to a reduction of attention to the females or to a severe deficit in sexual motivation.

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