are unphysiological or that they have never or rarely occurred previously in the rat's life. Many different conditions may result in altered evoked potentials. Such conditions include arousal, sleep, attention, distraction, pharmacological intervention, brain stimulation, and so forth. The data do suggest, however, that the mediating states do not commonly occur during operationally defined baseline periods and that, therefore, the conditioning process does not involve selection of a baseline state for production. It follows that the neural processes activated during conditioning represent a distinctive set of states. Thus, the conditioning technique may not be an appropriate way of isolating for study a process that is occasionally observed in a baseline period. These implications, on the one hand, restrict the applicability of operant neural conditioning for the purpose of direct study of normal psychology and physiology. On the other hand, the intriguing possibility remains that neural conditioning methods may allow experimental isolation of unusual or even otherwise unobservable patterns of novel behavior or cognition of potentially adaptive value.

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References and Notes

1. S. S. Fox and A. P. Rudell, *Science* **162**, 1299 (1968); *J. Neurophysiol.* **33**, 548 (1970); A. P. Rudell and S. S. Fox, *ibid.* **35**, 892 (1972); J. P. Rosenfeld, A. P. Rudell, S. S. Fox, *Science* **165**, 821 (1969).
2. J. P. Rosenfeld and R. Owen, *Physiol. Behav.* **9**, 851 (1972).
3. J. Kamiya, in *Altered States of Consciousness*, C. T. Tart, Ed. (Wiley, New York, 1969), pp. 519–529.
4. J. P. Rosenfeld, T. Bieneman, R. Cohen, A. Routtenberg, *Physiol. Behav.* **9**, 527 (1972).
5. Supported by NIH grants 5-550-5RR07028 and FR7028-05 to Northwestern University (J.P.R.).

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Sexual Behavior: Normal Male Patterning in Androgenized Female Rats

Abstract. *Female rats treated with testosterone as neonates and as adults exhibited a temporal patterning of male copulatory behavior identical to that of normal males, although such females displayed few intromission reflexes and almost no ejaculatory patterns. With prenatal, postnatal, and adult testosterone treatment, female rats displayed all the characteristic masculine responses and intervals, including the ultrasonic postejaculatory vocalization.*

Females of many mammalian species exhibit several of the motor elements of male copulatory activity, especially mounting of receptive females (*1*). Among rats, normal estrous females often engage in male-like mounting activity, but they rarely display those motor elements that characterize the male's penile insertions and ejaculations (*2*). When adult female rats are treated with androgen, the proportion of animals mounting is comparable to that of males, but phallic development is not enhanced and there are few behavioral insertion responses by such females (*3*). Combining perinatal (pre- and postnatal) and adult treatment of females with androgen augments phallic development and yields a concomitant increase in the occurrence of the motor components of insertion (intromission) as well as ejaculation. Such females are similar to males in the number of intromissions displayed preceding each ejaculatory pattern and in the duration of the postejaculatory intervals (*4*).

The problem here was whether female rats treated with androgen at different times during development would differ from normal males in the temporal patterning of copulatory acts. This question could not be adequately answered with traditional measures of copulatory activity. With such measures direct comparisons between males and females are meaningful only if the females have been treated so that they can display the reflex patterns of intromission and ejaculation. However, with some treatments females mount, but due to, for example, inadequate phallic development, they have a lower probability than males of displaying intromission and ejaculatory responses. In such cases conventional measures are inapplicable, and comparisons based only upon proportions of animals displaying intromissions and ejaculations are inadequate and even misleading measures of copulatory performance. Measures are required that avoid confounding sexual dimorphism in copulatory activity with sexual dimorphism in genital apparatus.

It is possible to measure the rate of attempted copulations independently of the occurrence of intromission and ejaculation. This can be accomplished by measuring the temporal periodicity of clusters of mounts, or "mount bouts." When rats copulate the male's mounts tend to recur in bouts of one or more mounts which may or may not eventuate in intromissions. Under common laboratory conditions, mounts within a bout tend to be separated by 1 to 10 seconds, and the intervals between bouts tend to be about 30 to 60 seconds. Normal males prevented from gaining intromission (by penile anesthesia or by occlusion of the female's vagina) nonetheless show the same temporal patterning of mount bouts as when intromission is possible. The mount bout is apparently a fundamental unit in the timing of male copulatory activity (*5*).

We now report that neonatally androgenized females, which rarely display intromission, as well as perinatally androgenized females, which normally display intromission, have a temporal patterning of mount bouts that is indistinguishable from that of males. In addition, females capable of displaying the ejaculatory response do not differ significantly from males in their preejaculatory patterning or postejaculatory behavior, including the ultrasonic postejaculatory vocalization.

Female rats ($N = 25$) were injected within 24 hours of birth with 0.5 mg of testosterone propionate (TP) in peanut oil subcutaneously (*6*). Males ($N = 12$) from different litters were untreated at birth, but otherwise reared similarly. After weaning, the rats were housed in unisexual groups. The animals were gonadectomized at 70 to 80 days, and implanted with a pellet of TP (10 mg subcutaneously) at about 120 days of age. Testing began about 2 weeks later. Experimental animals were placed in an aquarium (50 by 30 by 30 cm) with wood shavings on the floor 5 minutes prior to the introduction of a receptive female. Testing continued for 24 minutes. Up to four tests were given at weekly intervals. For each animal, testing was terminated after criterion was met in two successive tests or after four weekly tests (*7*). Data analyses were based on the final two tests and included either the first 12 minutes of mating behavior or the copulatory series prior to ejaculation when that occurred in less than 12 minutes.

The criterion for maters was met by 58 percent of the males and 76 per-

cent of the females. Of the males that mated, 100 percent achieved intromission and ejaculation. In contrast, 89 percent of the females displayed intromission and 5 percent ejaculation. The data in Table 1 are based upon the animals that met the mating criterion.

The females did not differ significantly from the males in their latencies to the first mount. Once mating began, the temporal patterning of the behavior was virtually identical in males and females, as reflected in the data on mount-bout period and time out. This identity was maintained despite significant differences between groups in the number of mounts and in the proportion of mounts that resulted in intromission. These differences may be attributable to a reduction in size and sensitivity of the females' phallus relative to that of the males. Phallic differences are apparently irrelevant to the temporal organization of mating once it starts.

In a separate experiment in a different laboratory with rats from another supplier, the copulatory behavior of female rats androgenized before and after birth was compared with the behavior of normal males (*8*). Pregnant females were injected on days 16 to 20 of pregnancy with 2 mg of TP in peanut oil subcutaneously, or with peanut oil alone. Female offspring of TP-injected females were injected with 0.5 mg of TP subcutaneously in 0.01 ml of peanut oil on days 1, 3, 5, 7, and 9 postpartum. Male offspring of the oil-injected females were injected only with oil on the same schedule. At 85 days of age, four oil-treated males and six TP-treated females were gonadectomized and implanted with 25-mg pellets of TP subcutaneously. Experimental testing was started at 120 days. Each animal was tested four times at 2-week intervals. Tests were ended with the first intromission after the third ejaculation. Data for the first copulatory series of the last three tests were analyzed and are summarized in Table 2 (*9*).

All the females demonstrated normal-appearing responses of intromission and ejaculation. There were no significant differences between males and females in measures interpretable as motivation for copulation (mount latency, postejaculatory interval) or temporal patterning (mount-bout period, time out). The only measure for which differences between the groups achieved significance was ejaculation latency, whereas the number of intromissions approached significance; both measures relate to the amount of time or stimulation needed for ejaculation, rather than to temporal patterning (*10*).

Table 1. Comparison of copulatory behavior of normal male rats with behavior of females injected with androgen neonatally. Group means are based upon individual means in the last two tests of animals reaching criterion as maters. See text for additional details.

Behavior	Males ($N = 7$) (Mean ± S.E.M.)	Females ($N = 19$) (Mean ± S.E.M.)
Mount latency (seconds)	87.6 ± 45.0	112.0 ± 39.9
Number of mounts without intromission	5.8 ± 1.5*	20.8 ± 1.5*
Number of intromissions	8.3 ± 0.8*	3.9 ± 0.7*
Proportion of mounts resulting in intromission	0.66 ± 0.07*	0.16 ± 0.02*
Number of mount bouts	11.4 ± 0.3	13.4 ± 0.6
Mount-bout period (seconds)	55.8 ± 5.5	59.0 ± 3.2
Time out (seconds)	51.4 ± 6.5	49.9 ± 3.2

* Differences between male and female groups (*t*-test) were significant, $P < .01$. In all other comparisons, $P > .25$.

Table 2. Comparison of copulatory behavior of normal male rats with that of perinatally androgenized females. Group means were computed from the means of individual animals' first ejaculatory series in the last three tests. See text for additional details.

Behavior	Males ($N = 4$) (Mean ± S.E.M.)	Females ($N = 6$) (Mean ± S.E.M.)
Mount latency (seconds)	45.3 ± 25.2	69.2 ± 40.1
Intromission latency (seconds)	66.9 ± 32.1	134.2 ± 69.8
Ejaculation latency (seconds)	329.1 ± 51.7*	973.0 ± 241.2*
Number of mounts without intromission	6.6 ± 2.2	20.9 ± 18.6
Number of intromissions	8.8 ± 1.0†	13.4 ± 1.0†
Proportion of mounts resulting in intromission	0.61 ± 0.07	0.50 ± 0.08
Mount-bout period (seconds)	48.6 ± 8.0	59.3 ± 3.5
Time out (seconds)	36.9 ± 7.9	44.2 ± 4.6
Postejaculatory interval (seconds)	339.5 ± 20.2	406.8 ± 34.2

* $P < .10$. † $P < .02$.

Finally, five perinatally androgenized females, treated identically to those in the preceding experiment, were placed with receptive females and their ultrasonic vocalizations were monitored by a heterodyne receiver (*11*), and also, in two instances, an oscilloscope.

All five females emitted 22-kilohertz vocalizations after ejaculation. They began 36 ± 13.1 seconds [mean ± standard error of the mean (S.E.M.)] after ejaculation, and they stopped 260 ± 30.3 seconds after ejaculation. The interval between ejaculation and next intromission was 354 ± 26.5 seconds. The ratio, time of vocalization termination to time of resumption of copulation (postejaculatory interval), was 0.74 ± .06. The comparable figure reported for males (same strain, different supplier) is 0.75 ± .03 (*12*). The frequency and amplitude of the vocalizations in the androgenized females were identical to those of the males. This equivalence in vocalization characteristics and duration suggests that the refractory state of which the vocalization is a reflection is also the same in androgenized females and normal males.

The females we treated with androgen perinatally had the potential for the full display of male copulatory behavior, including mounts, intromissions, and ejaculations. These females showed the characteristic behavior and temporal patterning of males both before and after ejaculation, including the postejaculatory vocalization and the normal postejaculatory intervals. The females treated only neonatally with androgen did not display the full pattern of masculine copulatory behavior; there were few intromission responses and fewer ejaculation patterns in this group. However, we employed a measure of sexual activity which revealed that underlying superficial differences between males and androgenized females in copulatory performance there is an identity of temporal patterning. Knowledge of this identity, and employment of the measures of temporal patterning that revealed this identity, may be useful in further analyses of the mechanisms and loci of the masculinizing action of perinatal androgen.

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References and Notes

1. F. A. Beach, in *Reproduction and Sexual Behavior*, M. Diamond, Ed. (Indiana Univ. Press, Bloomington, 1967), pp. 83–131.
2. The male's mounts without insertion, with insertion, and with insertion and ejaculation are clearly distinguishable by the morphology of the behavior, especially by variations in the movements of the hips and forelegs. Ventral views have amply confirmed the validity of the distinctions. The morphology of the female's masculine responses is identical to that of the male. However, we lack confirmation from ventral views that females displaying insertion responses have indeed achieved insertion of their phallus into the stimulus female, although in some cases they have an adequate organ to accomplish this. In this report the terms mount, insertion (intromission), and ejaculation refer only to the motoric pattern of behavior.
3. R. E. Whalen and D. A. Edwards, *Anat. Rec.* **157**, 173 (1967); R. E. Whalen *et al., Physiol. Behav.* **4**, 33 (1969).
4. I. L. Ward, *Horm. Behav.* **1**, 25 (1969); R. E. Whalen and R. T. Robertson, *Psychonom. Sci.* **11**, 319 (1968).
5. B. D. Sachs and R. J. Barfield, *J. Comp. Physiol. Psychol.* **73**, 359 (1970). The clustering of mounts in a bout is determined for scoring purposes by the mounting animal's behavior, rather than by elapsed time. If after a mount the animal does anything other than mount again, groom its genitalia, or orient itself toward the stimulus animal, then the preceding mount is assumed to have terminated the mount bout. The mount-bout period is the time from the first mount of one mount bout to the first mount of the next mount bout. This measure was termed the "inter-mount-bout interval" in Sachs and Barfield. Time out is the time from the last mount of one bout to the first mount of the next bout.
6. This experiment was conducted at Rutgers University. Long-Evans hooded rats were from Marland Farms, Wayne, N.J. Hormones in all three experiments were donated by P. Perlman, Schering Corp., Bloomfield, N.J.
7. The criterion for maters was a continuous display of mounting activity for at least 12 minutes after the first mount, or until ejaculation. Mating activity was considered discontinuous if there were more than 5 minutes between successive mount bouts. To be included animals must have achieved criterion in at least two tests. Of the animals that were excluded for failure to meet criterion, three females and one male did not mount at all, three males achieved criterion in one test only, and three females and one male mounted sporadically.
8. This experiment was conducted at the University of Connecticut. Long-Evans hooded rats were from Blue Spruce Farms, Altamont, N.Y.
9. The males had received two precastration tests. In order to better equate experimental variables, the first postcastrational test was omitted from analysis.
10. Further analysis revealed that those measures (ejaculation latency, number of intromissions, postejaculatory interval) that normally vary as a function of ejaculatory series did vary significantly with series in this experiment, indicating that the data were sufficiently reliable to detect expected changes in behavior. The obtained differences between groups in ejaculation latency and number of intromissions may again be attributable to differences in genital sensitivity. However, there were no significant differences between the two groups in phallic length, weight, or number of papillae (E. I. Pollak and B. D. Sachs, paper presented at Eastern Psychological Association convention, May 1973).
11. Holgate Ultrasonic Receiver, Holgate's of Totton, Southampton, SO4 3ZF, England.
12. R. J. Barfield and L. A. Geyer, *Science* **176**, 1349 (1972).

13. Supported by PHS research grants HD-04048 to B.D.S. and HD-04484 to R.J.B.

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Precision Selenodesy via Differential Interferometry

Recently (*1*), we described some astronomical applications of differential interferometry and the results from tracking the Apollo 16 Lunar Rover. The accuracy of this tracking and of similar interferometric observations of ALSEP (*2*) telemetry transmitters was degraded mainly by instrumental errors corresponding to uncertainties of tens of meters on the lunar surface. We report here the first results from the development and use of a new type of differential receiver to determine the relative locations on the lunar surface of two ALSEP transmitters. This receiver has made it possible to reduce random and systematic instrumental errors to nearly negligible levels—the equivalent of displacement uncertainties of centimeters on the lunar surface.

With the new differential receiver, the same S-band antenna, radio-frequency amplifier, frequency converters, and intermediate-frequency (IF) amplifiers are used to receive the signals from two ALSEP's simultaneously at each tracking station. Thus, the ALSEP signals, which originate at frequencies between 2275.5 and 2279.5 Mhz, appear at corresponding frequencies within an IF band centered at 10 Mhz. Any phase noise or drift introduced by the receiving system before this point (which includes all of the critical high-frequency portions) affects both ALSEP signals equally. From the IF signals, a system of phase-locked oscillators and single-sideband frequency converters then generates a frequency equal to 360 times the difference between the two ALSEP carrier frequencies, minus a constant bias (*3*). Cycles of this multiplied difference frequency are counted digitally. Subtraction of the numerical values of the counts obtained simultaneously at separate receiving stations yields the differential interferometric phase-delay observable.

This technique was used to observe the Apollo 12 and Apollo 14 ALSEP transmitters from stations in Merritt Island, Florida, and Goldstone, California (*4*), between approximately 06:30 and 12:30 U.T. on 28 October 1972. From these data we estimated four parameters representing the selenographic latitude and longitude of one ALSEP (*5*), the arbitrary initial value of the differenced counter readings, and the zenith delay of the atmosphere (assumed the same at both stations). The estimates for the relative positions of the ALSEP's are given in Table 1 and the postfit residuals in Fig. 1. The root-mean-square of the high-frequency "noise" in the residuals, equivalent in displacement on the moon to less than 15 cm, could easily have been lowered. The observations, spaced 1 minute apart and representing merely 0.05 second of signal averaging each, yielded formal standard errors of 50 cm for the components of the position on the lunar surface of ALSEP 14 relative to ALSEP 12. Had each point represented the full minute of averaging, the formal error would have been about 1.5 cm and the high-frequency "noise" correspondingly reduced.

With the random and instrumental errors reducible to such a low level, the accuracy in the determination of the relative positions of the ALSEP's becomes limited by other factors. We discuss these in order of increasing importance.

Differential effects of the neutral atmosphere influence the observable. These were modeled by a modified secant-zenith-angle law. At the beginning of the observation period when

Table 1. Solution for selenographic coordinates of ALSEP 14 from differential interferometry and coordinates of ALSEP 12. All coordinates except those describing the selenographic latitude and longitude of ALSEP 14 were held fixed at their nominal values, derived from analysis of Apollo Lunar Module tracking data (*13*). See text for a discussion of errors.

Site	Selenographic		Radius (km)	Baseline (km)
	Latitude (°S)	Longitude (°W)		
ALSEP 12				
Nominal	2.9903	23.4031	1736.000	
ALSEP 14				
Nominal	3.6656	17.4783	1736.393	
New minus nominal	−0.0412*	− 0.0221†		
ALSEP 12 to ALSEP 14				
Nominal				180.315
New minus nominal				0.531

* 1.249 km. † 0.668 km.