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Estrous Cycle in the Rat: Effects on Self-Stimulation Behavior

Abstract. *The performance of female rats, in pressing a bar for electrical stimulation of the hypothalamus, changes during the estrous cycle. Highest bar-pressing rates accompany the appearance of vaginal cornification. This increase is not an artifact of increased spontaneous activity at estrus, although the factors underlying these changes in activity may also mediate the changes in self-stimulation behavior.*

The rewarding properties of electrical stimulation of the forebrain in rats are influenced by motivational variables such as availability of food and water and systemic androgen levels, the onset of high-drive states usually being accompanied by increase in the rate of self-stimulation (see *1, 2*).

In one experiment, however, the hormonal induction of estrous behavior in ovariectomized rats had no effect on self-stimulation (*3*); lordosis was used to indicate the onset of estrus, but it is not certain that the hormonal treatment used had reinstated other aspects of the behavioral and physiological complex that is characteristic of estrus. For example, restoration of the high levels of activity seen in the normal estrous female seems to require more prolonged hormone-replacement therapy than was possible in the design of the experiment (*4*). The study I now report sought to determine whether changes in self-stimulation behavior accompany the normal course of the estrous cycle in intact rats.

Six female albino rats (200 to 300 g) were used; each had a monopolar 28-gauge electrode implanted in the lateral hypothalamus. Electrode loci were histologically verified as ranging between the level of the mammillary bodies and the region of the optic chiasm. The rats were maintained under controlled lighting: alternating 12-hour periods of darkness and light. The experiments were always conducted during the first 3 hours of darkness each day, with the apparatus illuminated by a red light. The course of the estrous cycle was followed by taking vaginal smears from each animal daily at the beginning of the dark period.

Anesthesia, surgery, or electrical stimulation interrupted the regular cycling of some rats. Only females whose normal cycle of cornification was not disturbed by the implantation of electrodes, or by the subsequent training and testing procedure, were used in the experiment. The animals were tested in a Skinner box having a floor 30 cm square. A sine-wave generator (50 cy/sec) delivered 0.5-second stimulation at the implanted electrode, on a continuous reinforcement schedule, when the rat depressed a bar. Four of the subjects were tested in a two-bar box in which operation of one of the bars was never reinforced. Food and water were available during all tests. Animals were trained to press for brain stimulation during 30-minute sessions on three consecutive days, during which time the electrical threshold for self-stimulation was determined; thereafter the stimulus intensity was set 15 μa above threshold for each animal, with the root-mean-square current values ranging from 40 to 125 μa. After training, the animals were tested daily throughout three complete estrous cycles.

Each test consisted of 15 minutes of acquisition (in which bar-pressing was reinforced by brain-stimulation) followed by a 30-minute extinction period with no stimulation. During the extinction period the following behavior patterns were recorded by use of a 5-second time-sample procedure: walking, rearing, grooming, sitting still, eating, and drinking. Testing did not begin on the same day of the cycle for every subject. There was no significant change in bar-pressing rates between the three estrous cycles.

Figure 1 summarizes the results for the group as a whole (*5*). In five of the rats, the highest mean score for self-stimulation occurred at estrus; in the sixth, on the day following estrus. For the group as a whole the self-stimulation score was significantly higher for the day of estrus than for the other days of the cycle, whether the other days were grouped as a single class ($p < .001$) or individually compared with the day of estrus [$p < .02$, $< .05$, and $< .05$, respectively (*6*)]. There was no significant difference ($p > .5$) between bar-pressing scores during the extinction period on the day of estrus and on any other day, although there was a significant tendency ($p < .05$) for the mean number of extinction responses to be lower at estrus, if the other days were considered as a single class. Responses on the no-reinforcement bar showed no significant change throughout the experiment. The behavior changes recorded during extinction were a guide to the activity changes accompanying the estrous cycle. The mean scores for the group show that on the day of estrus time spent sitting and grooming was less, and time spent walking and rearing was greater, than on other days of the cycle.

These observations agree with others obtained by different methods in indicating that female rats are most active at estrus (*7*). Although the

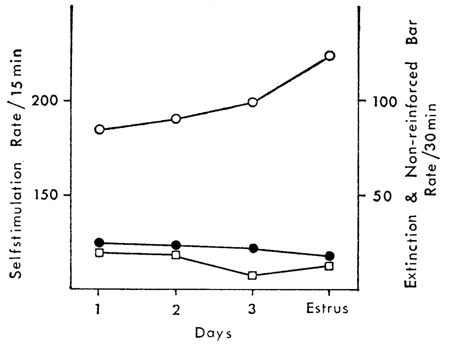

Fig. 1. Mean rates of bar-pressing recorded for all subjects throughout the experiment. Symbols: open circles, self-stimulation (*n*, 6); solid circles, extinction (*n*, 6); squares, responses on the no-reinforcement bar (*n*, 4).

animals were more active at estrus, the changes in self-stimulation behavior cannot be explained as an artifact of increased random activity in the Skinner box, because the extinction-period data, and the rates of response on the no-reinforcement bar, showed no tendency to rise at estrus; furthermore, during observation of behavior in the box, accidental "responses" were rare. My results therefore indicate that the onset of estrus correlates with a change in the reinforcing effects of brain-stimulation.

These results differ from those in an earlier report (*3*) that the hormonal induction of lordosis had no effect on self-stimulation by way of septal-area electrodes. Differences in loci of electrodes might account for this, although in male rats, with electrodes in the septum, self-stimulation rates are affected by changes in androgen levels (*2*).

A further difference between these experiments is that the hormone therapy used to induce lordosis in the ovariectomized rats is unlikely to have restored the levels of activity characteristic of normal estrous rats. Activity cycles and changes in sexual behavior seen during the estrous cycle are probably mediated by separate, though closely integrated, neuroendocrine mechanisms. Thus, in the ovariectomized rat progesterone is important for the restoration of lordosis but not for high levels of wheel-running; and, whereas single injections of estrogen and progesterone restore sexual responses, chronic application of estrogen is necessary to restore high levels of wheel-running (*4*).

Since in ovariectomized rats changes in sexual receptivity, indicated by the appearance of lordosis, can occur in the absence of changes in self-stimulation, it is possible that the effect I report is related more to factors underlying the activity changes accompanying the estrous cycle than to the changes in sexual receptivity. Similar interpretation is possible of reports that deprivation of food and water affect rates of self-stimulation; here again changes in motivation are accompanied by changes in activity (*8*), and it is not clear whether the self-stimulation effects stem directly from the specific drive states or from the activity changes associated with them. If the second alternative is correct, one may expect self-stimulation to be affected by spontaneous changes in gross bodily activity that are not obviously related to states of biological need. Such changes occur within the diurnal cycle of activity and rest in rats, and variations in self-stimulation behavior have been correlated with them (*9*).

A similar effect of cyclic changes in activity has been noted upon the threshold for electroconvulsive shock in rats (*10*); sensitivity to such shock is greatest at estrus and the effect is estrogen-dependent, progesterone having a slightly anticonvulsant effect. Diurnal fluctuation in electroconvulsive-shock threshold, which is qualitatively larger than the estrous-cycle variation, also occurs.

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Unit Responses from Commissural Fibers of Optic Lobes of Fish

Abstract. *The paired optic lobes of teleost fish are connected by two commissures. One of these, the tectal commissure, was studied with metal microelectrodes. Fibers are rhythmically active for prolonged periods in the dark and respond to light by a decrease in the rate of discharge. There is a rebound acceleration when the light is turned off. Each fiber is influenced by light in one eye only, and there is no response when light is projected into the opposite eye. This behavior resembles the "off" response recorded from the optic lobes and the optic nerve of fish. Unlike most units from the visual pathways of lower animals, single commissural fibers do not seem to give any recognizable response to patterned input such as small light or dark objects or small light sources stationary or moving anywhere in the visual field, nor do they respond to a vertical black bar moved over a white background.*

In fish, the left and right optic nerves cross completely, and each optic lobe of the brain receives direct information from the visual field of only one eye. Nevertheless, the perceptual processes of the two eyes are not independent, for behavior patterns based on visual cues learned through one eye are frequently found when the opposite eye is used alone (*1*). The physiological mechanism which maintains the perceptual unity behind such interocular transfer of learning is quite unknown. Behavioral experiments, paralleling those done on mammals, indicate that the commissural fibers joining the paired optic lobes are somehow involved (*2*).

The participation of cortical and midbrain commissures in the highest levels of mental activity in man and animals is of special interest because it raises the possibility that analysis of the messages carried by the commissures might give a clue to the way in which perceptual and mnemonic functions are handled in the brain. We have therefore studied the activity of fibers of one of the two commissural systems that connect the paired optic lobes of fish. Both commissures appear to be involved in interocular transfer of learned behavior (*2*). We now describe electrophysiological experiments on the tectal commissure; we have not yet been able to make satisfactory re-