Control of treadmill exercise of rats with hypothalamic stimulation

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Running and resting behavior of rats was measured during treadmill exercise under conditions involving (1) rear-shock avoidance, (2) continuous electrical stimulation of the hypothalamus, or (3) no rear-shock and no hypothalamic stimulation. Hypothalamic stimulation was superior for eliciting consistent running with a minimum of resting. A second experiment demonstrated that decreases in hypothalamically elicited treadmill running resulting from prolonged exercise could be counteracted by increasing the intensity of the hypothalamic stimulus. A third experiment suggested that very little training was needed to induce a high and consistent level of running performance using hypothalamic stimulation.

Forced exercise of small animals has taken several forms, including swimming, walking in a rotating drum, and running on a treadmill under a shock-avoidance contingency. Considerable training is often required with each of these methods and each has certain disadvantages. Swimming rats learn to "bob" up and down, thus exercising only intermittently. Often a substantial percentage of the Ss in a drum or on a treadmill must be discarded for failing to meet minimum performance requirements. In order to avoid this situation, young rats are often used and Ss are food deprived in order to increase their activity level. Even so, Ss may run only intermittently, momentarily experiencing the aversive consequences of not running.

This paper reports a technique for exercising rats by taking advantage of locomotor behavior elicited by electrical stimulation of the posterior hypothalamus. Recently, several investigators have reported that intense locomotor responses could be elicited by stimulation of the posterior hypothalamus and other areas of the brain (Gerbén, 1968; Christopher & Butter, 1968; Rosenquist & Hoebel, 1968). In the present investigations, rats with electrodes implanted to the posterior hypothalamus were stimulated while exercising on a treadmill. Running and resting behavior was measured under conditions of hypothalamic stimulation, rear-shock avoidance, or no shock and no hypothalamic stimulation. In addition, interactions between hypothalamic stimulation, fatigue, and training were investigated.

PRETESTING FOR ELICITED LOCOMOTION

Subjects

Ten male Sprague-Dawley rats (300-350 g) were implanted with bipolar electrodes to the posterior hypothalamus.¹ The stereotaxic coordinates were 3.25 mm posterior to the bregma, 0.75 mm lateral to the midline, and 9.00 mm below the surface of the skull, with the top of the skull in a horizontal plane. The rear quarters of the rats were shaved in order to facilitate contact with the shock grids used in Experiments 1 and 3 (see below).

Apparatus and Procedure

A Plexiglas activity wheel suitable for brain stimulation was used to screen Ss for hypothalamically elicited locomotor behavior. The wheel was 24 in. in diam and 3 in. in width, with a mercury swivel and lead mounted on a stationary wall of the chamber. Studs on the axle of the wheel actuated a microswitch, thus allowing measurement of the distance run by the S in units

of 2 in. During pretesting, 20-sec periods of hypothalamic stimulation were alternated with 100-sec periods of no stimulation. The electrical stimulus consisted of a train of biphasic square-wave pulse pairs (0.1 msec pulse duration, 0.1 msec interpulse interval, 100 pps) presented continuously during the 20-sec stimulation period. The peak stimulus current was varied during successive stimulation periods from 0.4, 0.6, 0.8, 1.0, and 1.2 mA. The distance run was measured under each stimulus intensity. If a S engaged in behavior that endangered the integrity of the electrode placement (e.g., jumping, twisting), stimulation was terminated immediately.

Results

Results of pretesting are shown in Fig. 1. All Ss except S 136 evidenced increases in locomotor behavior as a direct function of the stimulus intensity. S 136 showed elicited turning, but not wheel running. Thus, 9 of the 10 Ss were used in the subsequent experiments involving treadmill exercise. Three Ss were used in Experiment 1, two Ss were used in Experiment 2, and four Ss in Experiment 3. All Ss were maintained on free-feeding schedules of both food and water.

EXPERIMENT 1

The first experiment compared three methods of inducing rats to run on a treadmill: (1) avoidance of rear-shock, which is probably most commonly used; (2) elicited locomotion via hypothalamic stimulation; (3) a control condition during which neither hypothalamic stimulation nor shock avoidance was presented.

Apparatus and Procedure

Figure 2 shows a schematic diagram of the experimental

Fig. 1. Distance run by 10 Ss in a running wheel during 20 sec of continuous hypothalamic stimulation as a function of stimulus intensity.

Fig. 2. Schematic view of the experimental treadmill.

treadmill. The Plexiglas chamber on top of the treadmill was 9.5 in. L, and 3.5 in. W. At the rear of the chamber was a shock grid mounted on the levered inner wall. This wall was hinged at the top and actuated a microswitch (not shown) when moved backward $\frac{1}{4}$ in. at its base. The microswitch activated programming equipment that (1) delivered 60-cycle ac current across the grids for the duration of the microswitch closure, and (2) measured the duration of each microswitch closure. The lead wire for the hypothalamic electrode was inserted into the chamber through one of the air holes in the roof. The lead was sufficiently slack to allow the rat to move freely in the chamber.

During initial training, three Ss were run on the treadmill on 5 consecutive days, 30 min per day, under a shock-avoidance contingency (1.6 mA).² The subsequent testing sessions, during which the three methods were compared, occurred on 3 consecutive days. The duration of each testing session was 33 min, consisting of three consecutive 11-min periods. One of the three experimental methods was presented during each period, the intrasession and intersession order of presentation of these methods being counterbalanced according to a Latin square design. The transition from one method to the next was programmed during the first minute of each 11-min segment. This procedure consisted of gradually reducing the intensity of the previous stimulation and then gradually increasing the intensity for the next method. Under the rear-shock avoidance condition, the rear shock was raised to 1.6 mA. During hypothalamic stimulation, the intensity of the hypothalamic stimulus varied among the Ss. Under control conditions, the rear shock and the hypothalamic stimulation were both zero. The speed of the treadmill was gradually raised from 0 to 1 mph during the first minute of each session, and remained constant for the duration of the session.

Treadmill performance was measured during the final 10 min of each 11-min period. The amount of time that the microswitch was actuated was taken to be a negative measure of performance. This period of time will be referred to as "resting time," since it was assumed that each actuation of the microswitch resulted from a pause in exercise.

Results

Figure 3 shows minute-by-minute plots of the "resting time" under each experimental condition during each run. The data from each S is plotted separately. The "Position" designation refers to whether the data was obtained from the first, second, or third 11-min segment. Inspection of this figure indicates that hypothalamic stimulation greatly reduces resting time when compared to either the control or the rear-shock conditions. It is also interesting to note that both the rear-shock and control conditions produced more highly variable performance than did the hypothalamic stimulation. No consistent effect attributable to position was evident.

Fig. 3. Minute-by-minute graphs of resting time during 10 min under the three experimental conditions.

EXPERIMENT 2

Experiment 2 provided for an investigation of the efficacy of hypothalamic stimulation in counteracting lapses in exercise performance resulting from long periods of continuous exercise. Two naive implanted rats were trained for three daily 10-min sessions on the treadmill, a procedure similar to the hypothalamic stimulation conditions in Experiment 1. The treadmill speed was 1.5 mph. The test session was 1 h in length. The intensity of the hypothalamic stimulation was initially adjusted to yield initial minute-by-minute resting times under 10 sec. This procedure took less than 3 min for both Ss. Subsequently, any time the resting time per minute rose above 15 sec, the intensity of the hypothalamic stimulus was raised 0.1 mA. In this way, an attempt was made to reduce resting by eliciting more intense locomotion.

Results

Figure 4 shows minute-by-minute resting times for each S over the 60-min session. The horizontal line represents the 15-sec criterion. The vertical stippled lines indicate points at which the stimulus intensity was changed. The numbers at the top of the stippled lines represent the intensities of the hypothalamic stimulus. Inspection of this figure indicates that resting time per minute tended to increase with cumulative exercise time. However, this increase in resting time could be reversed by increasing the intensity of the hypothalamic stimulation. With the exception of the 1.4-mA to 1.5-mA increase for S 135, all increases resulted in a striking reduction of resting time. The exception resulted from elicited jumping that occurred when S 135 was first exposed to 1.5 mA. The intensity was lowered and the elicited jumping ceased. Later in the session, when S 135 was exposed to 1.5 mA, no jumping was elicited and a decrease in resting occurred.

Fig. 4. Minute-by-minute plot of resting time for two Ss during a 1-h session. The vertical lines represent the points at which current intensity was changed. The peak current is specified at the top right of each line. The horizontal line represents the 15-sec criterion for a change in current intensity.

EXPERIMENT 3

The third experiment compared the initial acquisition of treadmill running behavior under conditions of hypothalamic stimulation vs rear-shock avoidance. Four Ss, never before exposed to the treadmill, were run for four 11-min sessions, with all conditions similar to those in Experiment 1. The two running procedures were presented alternately during successive sessions. Two Ss received hypothalamic stimulation during Sessions 1 and 3 and rear-shock avoidance during Sessions 2 and 4, while the reverse was true for the other two rats.

Results

The total resting time per 10-min session for each S during each of the four sessions is shown in Fig. 5. Inspection of this figure reveals not only that hypothalamic stimulation yielded reliably less resting time, but that the resting time during hypothalamic stimulation was low from its first presentation. Apparently, the locomotor response to hypothalamic stimulation is "unlearned" in that little if any training is necessary for it to reach a high level.

DISCUSSION

The present experiments demonstrate the high degree of control of treadmill running attainable with hypothalamic stimulation. The consistency of the running response is much higher than under rear-shock avoidance contingencies. During the latter, Ss often alternated running with momentary resting until the treadmill carried them to the shock grid. A second advantage of hypothalamic-elicited treadmill running is that "fatigue" effects (that is, reductions in running) can be counteracted to some extent by variation in the current intensity. This is especially useful when running animals for long periods of time.

Fig. 5. Resting time per 10 min during four training sessions for four Ss. The solid bars represent the continuous hypothalamic stimulation condition. The diagonally striped bars represent the rear-shock avoidance conditions.

A third advantage is the small amount of training required to elicit a high degree of performance.

The method does, however, have possible disadvantages: (1) Adult rats should be used (over 250 g) since implantation that remains stable over a long period of time requires a full grown skull. However, once an adult rat shows elicited running, this response is generally reliable for the life of the electrode implantation. With proper handling of the animals, this period may be 3 months or longer, a period considerably longer than young rats remain good performers in the treadmill. (2) Hypothalamic stimulation has gross physiological effects that may be the source of artifactual data, depending on the dependent variables measured. However, the relative importance of the effects of hypothalamic stimulation vs the physiological correlates of aversive control resulting from the shock-avoidance contingency should also be considered. (3) It would probably be difficult to run several animals simultaneously since the intensity of the hypothalamic stimulation may vary among Ss. It may be possible to pretest Ss individually and subsequently run them simultaneously.

Hypothalamically elicited treadmill running is of potential use to exercise physiologists and to psychologists investigating behavior during exercise or hypothalamically elicited locomotion. The major advantage of this technique is that Ss exhibit more consistent running behavior, under a higher degree of control by the E than occurs in rear-shock avoidance in the treadmill.

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NOTES

- Histological analyses indicated that electrode placements were in the posterior and dorsomedial nuclei of the hypothalamus.
- This shock intensity was derived from pilot research that indicated that increasing the current above this value did not generally yield improved treadmill performance.