HYPOTHALAMIC AUTOSTIMULATION OF RATS IN RESPONSE TO LOW-FREQUENCY STIMULATION ON A BASIS OF LOCOMOTION

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Hypothalmic autostimulation of rats was studied in response to low-frequency stimulation at the rate of 30 to 7 Hz. The animals received brain stimulation in Skinner's chamber and on the basis of locomotion. The duration of the volleys of pulses as established by the animals during autostimulation on the basis of locomotion increased with a decrease in stimulus frequency. The pauses between the volleys and the duration of the volleys themselves increased with a decrease in stimulus strength. With stimulation at 7 Hz it was possible to choose a strength of current at which the total duration of the pauses was less than 10% of the total time of the experiment. Usually under these circumstances the duration of the individual pauses was less than 0.5 sec.

KEY WORDS: autostimulation of the brain; low-frequency stimulation; locomotion.

It was shown previously [1] that, using a chamber with a pedal and a frequency of stimulation of 1-5 Hz, it is possible to select a strength of current at which the rat's brain is subjected to almost continuous autostimulation (AS). If the brain stimulation during AS was applied only during locomotion of the rat, during continuous AS continuous running of the animal would be observed.

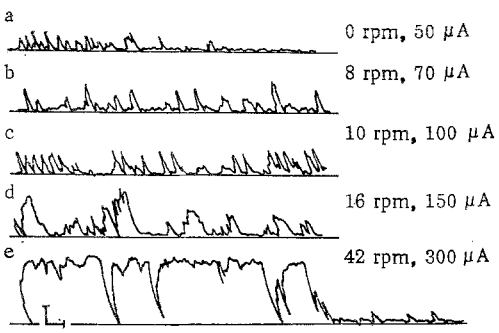

Fig. 1. Record of running speed of rat No. 10 stimulated at a frequency of 30 Hz and with currents of different strengths. Mean running speed and current strength shown by numbers at the side of each curve. Upward deviation of current corresponds to increase in running speed. Calibration, bottom left, scale of figure (6 sec and 8 rpm, respectively). Remainder of legend here and to Figs. 2 and 3 explained in text.

The object of this investigation was to obtain continuous AS on the basis of locomotion and to investigate the animal's behavior in that situation.

EXPERIMENTAL METHOD

Bipolar electrodes were implanted into the region of the lateral hypothalamus [4] of albino rats weighing 250-300 g to correspond to the cranial coordinates: 2.5 mm caudally to the bregma, 1.3-1.7 mm laterally to it, and 7.5-8 mm deep from the surface of the skull. The diameter of the electrodes was 40 μ. Electrical AS of the brain was studied in a chamber with a pedal, in which the rats received brain stimulation by pressing on the pedal, and in a chamber with a wheel, in which the brain was stimulated after running on the wheel [2]. The chamber with the wheel consisted of a plastic box measuring 10 × 12 × 8 cm, the base of which was the surface of a vertically mounted drum [2]. The diameter of the drum was 30 cm and its width 6 cm. As the rat ran the wheel turned. The speed

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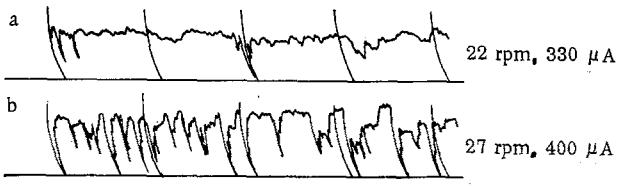

Fig. 2. Record of running speed of rat No. 3 during stimulation at 7 Hz and with currents of different strengths. Scale and legend as in Fig. 1.

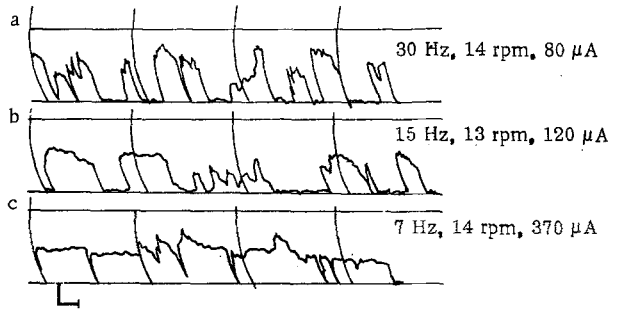

Fig. 3. Record of running speed of rat No. 10 during stimulation with different frequencies and strengths. Scale and legend as in Fig. 1.

of rotation of the wheel and the number of revolutions per minute were recorded. The rats received stimulation if they ran at speeds of more than 6 rpm (about 9 cm/sec). Square pulses, 1 msec in duration, and at frequencies of 30, 15, or 7 Hz, were used for stimulation.

With each frequency of stimulation and each strength of current, the duration of the investigation was not less than 5-10 min. Experiments were carried out on 12 animals.

EXPERIMENTAL RESULTS AND DISCUSSION

With a frequency of stimulation of 30 Hz and a current strength subliminal for AS, the rats performed a few short runs in the course of the first 1-2 min. They then stopped running and no longer turned the wheel (Fig. 1a).

For each strength of current there was a maximal running speed attainable in the single runs. Usually every minute the rat performed several runs at near-maximal speed. Often these runs alternated with series of 2 to 10 slower and shorter runs (Fig. 1b, c, d). As the strength of the current was increased, the duration and frequency of the runs at high speed and also the maximal running speed all increased. However, when the running speed reached 20-30 rpm and the duration of the runs 6-10 sec, the mean number of runs per minute sometimes decreased (Fig. 1c, d). Finally, with a very strong current, runs lasting several tens of seconds and at speeds of 30-40 rpm were observed (Fig. 1e). The rats' behavior in that case was unstable. Having completed several such runs in succession, the rats introduced long pauses. With such strong currents the rats often ceased their high-speed running and rested with all their paws on the surface of the drum. This method of stopping differed sharply from the usual method, when the rat simply reduced its running speed.

With a frequency of stimulation of 15 Hz the rats' behavior was indistinguishable qualitatively from that observed at 30 Hz. After the change in frequency of stimulation, but with the same strength of current, the number of runs per minute decreased, the maximal speed of running was reduced, and often the duration of the runs was increased. After an increase in the strength of the current the total number of runs also increased. At 15 Hz no runs with speeds of 30-40 rpm and with durations of several tens of seconds were observed. Direct motor responses to stimulation occurred sooner than runs of this type.

The mean running speed increased with an increase in the strength of the current. During stimulation at 30 Hz the mean running speed could change from 6-12 to 20-40 rpm simply as a result of an increase in

the current strength. During stimulation at 15 Hz no consistent behavior could be observed in most rats during application of a weak current, allowing the animals to run at a speed of 14-20 rpm.

With stimulation at 7 Hz the rats started AS only if the current strength permitted running at a speed of 14-20 rpm. The duration of the pauses during running in this case was short, not more than a fraction of a second (Fig. 2). Virtually continuous brain AS was observed. An increase in the current strength led to an increase in the number of pauses, but had little effect on their duration (Fig. 2b). After such an increase in the current the rats became more excited, they nosed and sniffed, and so on. Currents of great strength were therefore not used.

Having chosen the appropriate strength of current for 30, 15, and 7 Hz, an approximately equal running speed for the same animal could be obtained. Under these circumstances the equal running speed was achieved in different ways (Fig. 3). At 30 and 15 Hz the rat's running consisted of an alternation of runs and stops (Fig. 3a, b). AT 7 Hz the rat's running was virtually continuous (Fig. 3c). The total duration of pauses was much shorter than the total duration of the experiment.

Seven rats of this series also were tested in a chamber with a pedal using stimulation of the same strengths and frequencies. In response to a decrease in the frequency of strength of stimulation, an increase in the duration of the volleys of pulses and a decrease in the frequency of pressing on the pedal were observed. With currents of strength so that during AS on the basis of locomotion the mean speed was 8-12 rpm, in the chamber with the pedal the mean duration of pressure on the pedal was 1.5-1.6 sec and the frequency of pressing 15-30 per minute. With an increase in the strength of stimulation (when the running speed was 16-20 rpm) the frequency of pressing on the pedal also was increased to 90-120 and the duration of the volleys fell to 0.2 sec or less.

The frequency of pressing on the pedal was always greater than the frequency of the runs during AS, and it was altered more sharply than the running speed during a change in stimulation. The mean duration of pressing on the pedal in the overwhelming majority of cases was less than the mean duration of the runs. Even long pressing on the pedal never reached the duration of the runs with a near-maximal running speed.

Continuous AS in the chamber with the pedal during stimulation at 7 Hz was observed in only two of the seven rats. The running of these rats was very uniform, with only a few pauses. The mean running speed was one of the lowest, 14-16 rpm. The remaining rats, exposed to stimulation of the same strength and frequency, did not carry out continuous AS, although the mean duration of the pauses was reduced after a decrease in the frequency of stimulation. AS based on locomotion when the frequency of stimulation was 7 Hz could be regarded as virtually continuous. The total duration of the stops and, correspondingly, of the pauses was only a small fraction of the total duration of brain stimulation.

Although all that was necessary to obtain stimulation was to develop a speed of 6 rpm, stable behavior of the rats was observed at much higher running speeds. Moreover, speed depended on the parameters of stimulation. Even when the mean running speed was approximately constant despite differences in the frequency of stimulation, the speed within the runs and the duration of the runs varied. These facts indicate that brain stimulation in the presence of AS had a marked effect on the running speed of the rats. The activating effect of stimulation of the lateral hypothalamus on running speed in various situations has been reported by other workers [3, 5].

The higher frequency of AS and the shorter duration of the volleys in the chamber with the pedal when compared with AS in the chamber with the wheel could be attributed to the activating effect of brain stimulation during AS on the animal's motor behavior. In the chamber with the pedal the activating effect of stimulation was to some extent contradictory to the task of maintaining a static posture, when the rat kept the pedal pressed down. In the chamber with the wheel, brain stimulation, which "activated locomotion," thus "helped" the animal to maintain a high running speed.

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