Conditioned Motor Reflexes in Cats with Damage to the Globus Pallidus

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Summary. 1. Unilateral destruction of globus pallidus does not influence natural conditioned reflexes. Bilateral destruction results in temporary disappearance of natural as well as artificial conditioned motor reflexes. Further training is necessary for the reestablishment of these reflexes. However, the training period is twice that required in the preoperative period. Reestablished conditioned reflexes manifest themselves with long latency. Movements are performed with accuracy but very slowly.

2. After partial bilateral destruction of the pallidum, animals that have been trained not only to press a pedal, but also to make a choice between a right or a left feeding tray, lose the latter ability. After the reestablishment of conditioned reflexes, the animals make a correct choice of side only 50—70% of the time.

3. After total bilateral destruction of globus pallidus, the animals lose artificial conditioned reflexes; these are not reestablished even after four months of training, though natural conditioned reflexes can be reestablished but with great difficulty.

The results suggest that globus pallidus has a close relationship with the mechanisms of learning and memory.

Key Words: Striopallidal system — Globus pallidus — Conditioned motor reflex — Learning — Memory

Introduction

Previous experimental investigations have led us to the conclusion that the morphophysiological architecture of conditioned motor reflexes is set up by the dynamic interaction between anatomic structures located along the horizontal as well as the vertical axis of the central nervous system (Gambarian, 1963, 1968a). Furthermore, it was suggested that in the process of elaborating conditioned motor reflexes, the closure of temporary connections takes place within the “cortex-cortex” system as well as within the “cortex-subcortex-cortex” system (Gambarian, 1959, 1968b, 1969). Such a conclusion sets the problem of determining the extent of participation of subcortical structures in the process of elaboration and performance of conditioned reflexes. To this end, the role and specific significance of the globus pallidus have been investigated. The need for such an investigation is also suggested by the fact that existing relevant albeit scanty data are quite contradictory. Whereas some authors claim that lesions of the globus pallidus have either no effect on conditioned motor reflexes (Kourayev, 1968) or only little effect (Laursen, 1963a, 1963b), others maintain that partial (Lissak and Endrőczí,
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1965) and total bilateral lesions (Thompson, Malin and Hawkins, 1961; Oleshko, 1964) result in a complete disappearance of established conditioned reflexes and preclude the elaboration of new ones.

Methods

The experiments were carried out on 36 adult cats. With some cats, only natural feeding motor reflexes were investigated before and after destruction of the globus pallidus, while in another group both natural and artificial feeding motor reflexes were studied. The elaboration of natural reflexes was carried out in a special chamber, one wall having been provided with a transparent sash-window outside of which the feeder was placed. The cat was trained to press the sill of the window (which served as a pedal) when the meat appeared outside the window. The sight of meat was, therefore, a natural conditional signal. The window opened automatically when the pedal was pressed, and the cat could get the meat by stretching out its paw. The equipment permitted recording the moments of pressing the pedal and of seizing the meat. The time interval between these two operations is termed "time of conditioned motor reaction", which is an objective index of the rate of motor performance.

Artificial conditional reflexes consisted of pressing the pedal to a sound or light signal and obtaining food automatically. With this method we first established natural conditioned reflexes, and later, artificial ones. A full description of the technique of elaborating natural and artificial conditional reflexes is given in a previous article (Gambarian et al., 1966).

In order to study more complex forms of behaviour, the experiments were carried out in a chamber provided with two feeding trays on opposite sides. The cats were trained to approach the tray on the right side and press the pedal at one signal (bell), and at the other signal (metronome), to approach the tray on the left. Thus, in addition to the training on the simple motor reflexes, the cat was trained to make the correct choice of side, and only in the case of a correct choice would the pedal pressing be followed by food reinforcement.

Destruction of the pallidum was carried out electrolytically under nembutal narcosis (40 mg/kg), and the electrodes were placed according to the stereotaxic co-ordinates of Jasper's and Ajmone-Marson's atlas (1954). Electrocoagulation was carried out with direct current (5—8 mA) for 1—1.5 min and, in order to produce as complete a lesion as possible, it was repeated at two or three points bilaterally (Fr = 12.5; L = 8.5; H = 1.5 and Fr = 14.5; L = 7.5; H = 2).

The operated animals were kept in special rooms where they could move about freely. Upon termination of the experiment, and with the animal under narcosis, the brains of all the animals were perfused, removed, and fixed in 10% formalin. Celloidin sections were cut at 25 μm; every tenth section was stained with haemotoxilin — eosin and examined under the microscope.

Results

In the early post-operative period (for 3—6 days or more) the characteristic symptoms of pallidal lesions were depression and drowsiness, aphagia and adynamia, and strong suppression of pain and orientation reactions. Spontaneous movements were exceedingly slow and constrained. These movements often ended in motionless states (freezing) in unnatural poses. By the end of the first week and at the beginning of the second the animal displayed compulsive circling movements which gradually diminished with the passing of weeks. Motor and sensory disorders were observed during this period (crossing, spreading and folding of limbs). These disorders may be attributed in part perhaps to destruction of the capsula interna (Fig. 7). Depending upon the degree of destruction, this syndrome abated or disappeared in 3 or 4 weeks, but the disorders in conditioned reflex activity persisted.

Natural Conditioned Reflexes

In all three cats with unilateral destruction of the globus pallidus, and on the fifth or sixth day — when the unconditioned feeding reflexes had reappeared — the