DIMENSIONS OF THE HIPPOCAMPUS, MEMORY, AND LEARNING IN THE ONTOGENESIS OF RATS

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Damage to the hippocampus in 20-, 50-, and 110-day-old rats impairs the processes of learning and short-term memory in them. In 50-day-old rats, hippocampectomy has less of an influence on the process of learning and memory than for 20- and 110-day-old animals. The anatomic and physiological characteristics of the hippocampus in 20-day-old rats may be evidence of a special importance of this formation at the early stages of ontogenesis, when the cerebral cortex is still insufficiently mature and its associations with other structures have not been entirely formed. The nonlinear nature of the dependence of the disruption of learning in rats of different ages after hippocampectomy suggests that the function of the rat hippocampus undergoes changes during the process of individual development of the animal.

INTRODUCTION

There is no doubt of the participation of the hippocampus in processes of memory and learning in adult animals. It is of interest to compare the periods of its maturation during ontogenesis with the nature of the participation of this structure at different stages of individual development in the processes of memory and learning. A detailed investigation during ontogenesis is also interesting in connection with the fact that the hippocampus, as an older cortical formation, should surpass the neocortex in degree of maturity of axo-dendritic and axo-somatic contacts by the time of birth of the animal and should also be superior in rates of formation of the synaptic apparatus in the course of postnatal ontogenesis [1-5]. The more substantial level of development of the hippocampus by the time of birth in comparison with the neocortex indicates that precisely the hippocampus establishes definite associations with the subcortical centers, responsible for elementary behavior associated with the maintenance of the individual at early stages of postnatal ontogenesis [6, 7]. And yet, the hippocampus reaches full maturity at a relatively late stage of ontogenesis. This maturity corresponds to a high level of integration, permitting the animal to be autonomous [8-10].

MATERIAL AND METHOD

The work was conducted on 58 male white rats. At ages of 18-20, 50, and 110 days, the operation of destruction of the hippocampus according to the Mering procedure [11], permitting a substantial degree of destruction of the hippocampus while the neocortex lying above it is relatively preserved, was performed on them. Learning, i.e., the development of a response of successive alternation of right- and left-side runs, reinforced with food [12], was begun 10-15 days after the operation (at 30, 60, and 120 days of age, respectively). With such a method of training, the conditioned stimulus is not light, sound, etc., but the external appearance of the chamber, as well as olfactory, proprioceptive, and vestibular impulsation. In other words, such a method sets increased requirements for associative activity of the brain. Correct selection of the direction of running is possible only if traces of the direction of the previous run are retained in the nervous system. The enumerated facts permit us to consider that the method is adequate for the study of the process of memory in animals. Training can be conducted at intervals between runs lasting from several seconds to several hours. During training, each animal performed up to 400 runs. The performance of an average of 80% correct responses for the group during two days in a row was considered as the criterion of learning. At the end of the experiment, a histological analysis of the volume and localization of the damage to the hippocampus was performed. It was established that in all cases primarily the
dorsal portion of the hippocampus was destroyed; the parietal lobe of the cerebral hemispheres was little-affected by the operation (Fig. 1).

EXPERIMENTAL RESULTS

A nonlinear dependence of the effect of the operation on the ability of rats to learn responses of alternation of runs was detected. The graphs in Fig. 2 characterize the dynamics of the learning of the operated-on and intact rats of different ages. It can be seen that only 60-day-old hippocampectomized rats reached the 80% criterion of learning. Among the adult rats (age 120 days), despite 400 runs, the alternation did not exceed the 50% level of performance, i.e., remained within the limits of randomness. The learning of young (30-day-old) rats was somewhat more successful, but among them also, by the end of the experiments, the level of reflexes did not exceed 60-70%. The control animals of all ages reached the criterion of learning after 50-100 runs.

Table 1 presents data showing the percentage of animals in the group that developed the reflect with a definite duration of the pause. The development of the response of successive selection of the direction in the case of a successive increase in the trace pause between runs is possible in the operated animals in the case of intervals not exceeding 15 sec (younger and older groups) and 2 min (animals of the middle age group). Among intact rats, however, learning occurred with a far longer time interval - 20-120 min, depending on the age. Thus, among hippocampectomized rats, the duration of retention of traces in the short-term memory is extremely limited.

A characterization of the short-term memory with the aid of the coefficient of linear regression, showing the change in the number of correct responses during one day [13], gives evidence of its absence in 30- and 120-day-old rats and a very low value in 60-day-old hippocampectomized animals. Among the intact rats of all age groups, the short-term memory had high indices according to this criterion.

<p>| TABLE 1. Number of Animals (% of total number) in the Group That Developed the Reflex with a Definite Duration of the Trace Pause |
|---|---|---|---|---|---|---|---|---|---|
| Age of animals (days) | Percentage of animals which different durations of the trace pause (min) | | | | | | | | |</p>
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<tr>
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<th>hippocampectomized</th>
<th>intact</th>
<th>15 c</th>
<th>2</th>
<th>15 c</th>
<th>2</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>60</th>
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<td>55.5</td>
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<td>100</td>
<td>100</td>
<td>50</td>
<td>16.7</td>
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<td>60</td>
<td>77.7</td>
<td>33.3</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>88.8</td>
<td>66.6</td>
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<td>120</td>
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