DEVELOPMENT OF SPONTANEOUS MOTOR ACTIVITY IN RATS IN THE EMBRYONIC AND EARLY POSTNATAL PERIODS

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The development of spontaneous motor activity was studied by a graphic recording method. The prolonged movements of embryos and newborn rats can be subdivided into progressively shorter complexes. An increase in amplitude of extensor movements of "jerky" type is achieved through superposition of several extensor movements into one. Prolonged lateral contractions of the trunk in the embryos have the character of tetanized tonus. The rhythmic phase of the scratch reflex is formed gradually and reaches the characteristic level of adult animals in rats aged 10 days.

Spontaneous motor activity appears in rats in the embryonic period on the 16th-17th [18, 24, 25] or, according to some observations [26], on the 18th day. Initially the spontaneous movements of rat fetuses are reflex responses. In rats, as in other mammals [3, 13, 19], motor activity develops in a series of stages which are determined by the morphological and functional maturation of particular zones of the central nervous system: the stage of primary, local, isolated movements of the head and limbs, the stage of primary generalization of reflexes consisting of fast extensor movements of the trunk, the stage of secondary generalization of reflexes consisting of generalized slow, tonic movements of the trunk, and the stage of specialized motor reflexes.

By contrast with earlier investigations based on visual observations or photographic recording, a graphic method [7] was used in this investigation, thereby considerably increasing the scope of analysis of development of motor activity in warmblooded animals.

EXPERIMENTAL METHOD

While the fetal movements were recorded the fetus remained connected with the mother, which was anesthetized with urethane (1.5 g/kg), through the umbilical cord. The fetuses were taken from the uterus one at a time and placed on a special platform immersed in physiological saline at 38°C. Motor activity was recorded for 5 min. Movements of the hind limbs, head, and trunk of the fetuses were recorded from the 17th until the 21st day. In the postnatal period movements of the hind limbs only were recorded from the 1st until the 20th day of life. The results described below were obtained by analysis of records of the movements of 30 fetuses and 117 young rats.

EXPERIMENTAL RESULT

The first appearance of spontaneous motor activity was observed in 17-day fetuses. At this stage slow "swimming" movements of the limbs, performed without interruption for a long period (Fig. 1a), and fast extensor movements of the head, as a rule isolated, lasting about 265 msec (Fig. 2a, b) were recorded. Early local movements of the fetuses appear after connections have become established between afferent and efferent neurons and ipsilateral unisegmental arcs consisting of three neurons constitute their mechanism [27, 28]. In some fetuses extensor movements of the head were accompanied by extensor movement of the trunk, reflecting the gradual unification of the maturing foci into a central nervous system [2, 4, 6, 20].

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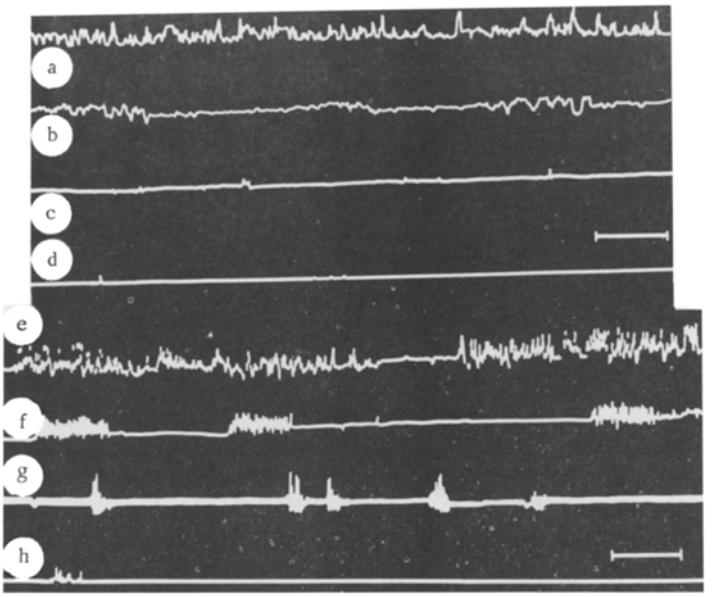

Fig. 1. Spontaneous movements of hind limbs of rats in fetal and early postnatal periods. Fetal period: a) 17 days, b) 18 days, c) 19 days, d) 20 days, e) newborn rats. Early postnatal period: f) 3 days, g) 9 days, h) 20 days. Time 10 sec.

On the 18th day the protracted, tonic character of the movements became particularly pronounced. Prolonged flexion of the trunk in the lateral direction, lasting from 15 to 60 sec, appeared. These movements were not single and continuous (Fig. 2e, f), but consisted of superposed separate short movements, with the result that the movement itself became like tetanized tonus in character. Extensor movements of the body also had a tendency to change into more protracted movements through the fusion of two or more extensions. Their duration was almost doubled (Fig. 2c). Movements of the limbs were retarded, but they were not yet continuous in character and they alternated with intervals of immobility, so that regularly repeated movement complexes were formed (Fig. 1b). The general motor activity was increasing at this period. The appearance of prolonged tonic contractions of the fetal trunk was due to the inclusion of the medulla and midbrain together with, evidently, the thalamo-pallidary system, in combined activity with the spinal cord [5, 11, 14, 17]. Rapid extensor movements and slow tonic contractions of the fetuses, despite the absence of differentiation of the muscles into tetanic and tonic fibers at this period [21, 22], are evidence of the important role of the nervous system in the formation of muscular contraction at this stage.

On the 19th-20th day the fetal motor activity was sharply reduced and only occasional single movements of the limbs (Fig. 1c,d) and head were observed. The extensor movements at this time again occurred at the same rate as on the 17th day, but the "superposed" form of these contractions was now predominant and accounted for 81% of all extensor movements. Superposition of individual extensor movements into one was accompanied by an increase in amplitude of the contraction (Fig. 2d).

After birth motor activity rose sharply, and was particularly high in the rats during the first two days (Fig. 3), after which it decreased. By contrast with the prolonged, slow movements of the 17-day fetuses there were clearly-defined phasic, mainly alternating, rhythmic movements (a rhythm of the 1st order). The limb movements once again became almost continuous in character to form complexes lasting about 30 sec, or a rhythm of the 2nd order [9] (Fig. 1e). The decrease in motor activity on the subsequent days was accompanied by shortening of the duration of the complexes and lengthening of the intervals of immobility (Fig. 1f, g, h). According to the literature, prolonged, continuous activity in newborn animals and infants is due to predominance of their thalamo-pallidary system and immaturity of their striatal and pyramidal systems. Maturation of the corpus striatum has an inhibitory effect on impulses arising from the globus pallidus, and this evidently results in the breaking up of the long complexes into shorter ones [15, 23]. A similar picture was observed previously when movements of chick embryos

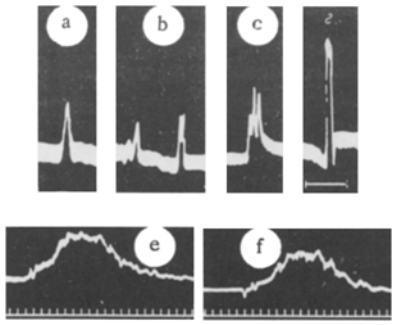

Fig. 2

Fig. 3

Fig. 2. Fast extensor movements of "jerky" type in rat fetuses aged 17 (a, b), 18 (c), and 20 days (d) and prolonged lateral flexion movements of the trunk in animals aged 18 days (e, f). Time 1 sec.

Fig. 3. Duration of spontaneous motor activity of hind limbs of rats in the early postnatal period. Ordinate, duration of spontaneous activity (in sec), movements recorded for 5 min; abscissa, age in days.

[8] and young rabbits [10] were recorded. On the 9th day of life the principal form of spontaneous motor activity consisted of short bursts of alternating movements. By the time that the animals had acquired sight (14th-15th days) the general motor activity of the young rats was considerably reduced (Fig. 3).

Besides alternating movements, the development of a scratch reflex and its rhythmic stage was observed. The rhythm of the spontaneous scratching movements in day-old rats was 2.6 ± 0.1/sec, in rats aged 5 days it was 4.3 ± 0.3/sec, and in rats aged 10 days, 6/sec, just as in adult rats [1, 12]. After the age of 9 days the number of spontaneous scratching movements was considerably reduced, while in rats aged 20 days, which were able to see and to stand, there was now extremely little spontaneous motor activity, and the rats could remain for lengthy periods in a state of rest.

According to Ukhtomskii [16] physiological rest provides a means for adequate response to changes in the external environment; it is a facility acquired during ontogeny and phylogeny and it is based on high lability of nervous structures [16].

It can be concluded from the results described above that in the early stage of development the processes taking place in the central nervous system have a well defined rhythmic character. Later the activity of these rhythmic mechanisms diminishes and they are largely superseded by inborn or acquired motor activity of a nonrhythmic character.

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