ELECTRICAL ACTIVITY OF THE CEREBRAL CORTEX OF APES DURING DEVELOPMENT

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Available information on the electrical activity of the cerebral cortex of apes of different ages applies only to the macaque rhesus [10, 12].

The object of the present investigation has been to study the EEG of various species of lower apes, starting at the first few days of life and continuing to old age. Our observations were made on macaque rhesus, pavian hamadryads, and Cercopithecus callithricus. All the experimental animals were acclimatized to the conditions of the Sukhumi animal house, and most of them were third or fourth generation apes born there.

EXPERIMENTAL METHODS

The EEG was taken using bipolar needle electrodes inserted subcutaneously over the frontal and occipital regions of both hemispheres. Recording was made with 8 leads from 6 points, as shown in Fig. 1; a "Kaizer" electroencephalograph was used. Because of limited space, we report here only the results of the fronto-occipital lead. During the experiments the animals were kept in a dark screened room, and were held by an assistant. It most cases, the EEG was recorded with the animal in a waking but relaxed condition. Sometimes, during the experiment the young apes were in a condition of tremor.

For the first few weeks of life the newborn apes (3 pavian hamadryads, 3 macaque rhesus, and 3 Cercopithecus callithricus) were used for the experiment daily, or every other day; later, until the age of 3-4 months, experiments were made every 10 days. Animals between 1 and 4 months (7 pavian hamadryads, 3 macaque rhesus and 6 Cercopithecus callithricus), were examined every 2 weeks until the age of 5 months, and subsequently monthly until 1 year old. Also, apes of different age groups were taken: young animals aged 1-2 years (8 pavian hamadryads, 7 macaque rhesus and 8 Cercopithecus callithricus), adults aged 3-4 years (8 macaque rhesus and 3 Cercopithecus callithricus), and old apes aged from 14 to 21 years (2 pavian hamadryads and 10 macaque rhesus). These latter apes were studied for a short period of 2-3 days in succession; during this period a number of EEGs were taken.

Altogether 71 apes were studied, comprising 20 pavian hamadryads, 31 macaque rhesus monkeys, and 20 Cercopithecus callithricus.

EXPERIMENTAL RESULTS

In the first few days of life of the lower monkeys of the species we investigated rhythms characteristic of the cerebral cortex were recorded from the fronto-occipital leads. These waves were of the α-rhythm (8-12 per second) and β-rhythm (16-32 per second) types, but they occurred only occasionally and were of very low amplitude (20-40 μV). The principal waves had a frequency of 1-3 and 4-6 per second, and were of greater amplitude (40-110 μV). In all the apes, in the first days of life, no regular rhythms with groups of waves of a definite frequency were found. There was mainly an irregular distribution of the oscillations of various periods (Fig. 1,A and B).

The EEG of the Cercopithecus callithricus differed somewhat from that of the pavian hamadryads and macaque rhesus monkeys. The amplitude of the oscillations was higher and the high frequency components were more marked, although again the slow waves predominated (Fig. 1C).

In monkeys of all the species investigated, at the age of 1 month, the slow waves of 4-6 per second continued to preponderate (Fig. 2, A, B, and C), but they had become more regular, and some grouping could be observed. Their amplitude had been increased considerably to 30-90 μV, especially in the Cercopithecus callithricus (30-180 μV).

The amplitude of all kinds of electrical oscillation attained a maximum at 6-8 months. The amplitude of the slow waves at this age varied between 100 and 360 μV, the α-rhythm varied from 50-300 μV, and the β-rhythm from 20 to 120 μV. At this age, the regularity of the α-rhythm waves was more marked, and the regions of the regular rhythm were more extensive than in the 1-month-old animals.

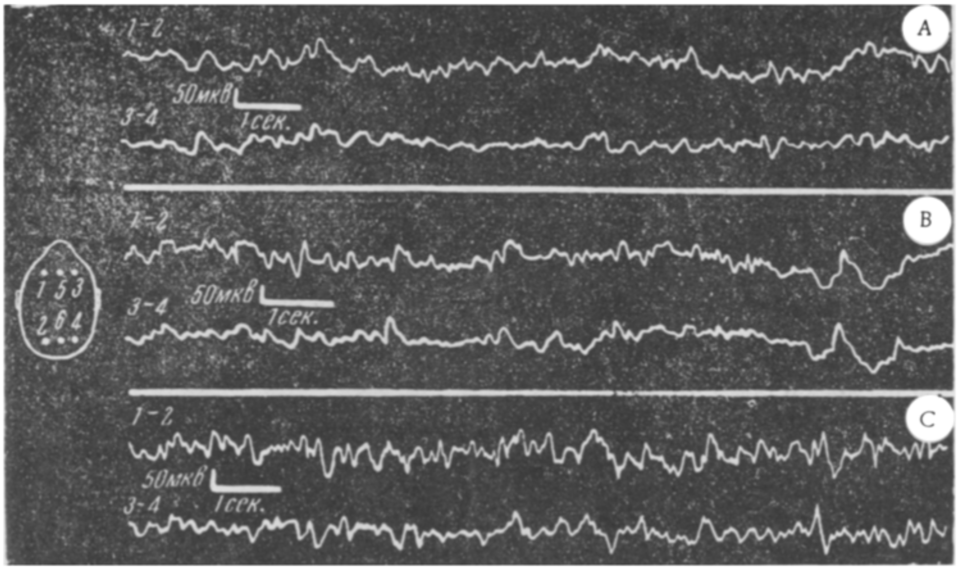

Fig. 1. EEG of young pavian hamadryad (A), macaque rhesus (B), and Cercopithecus callithricus (C) aged 2 days. The diagram on the left shows the 6 points from which the EEG was recorded.

Vertical scale(s) in millivolts (мв) or microvolts (мкв); horizontal scale(s) in seconds (сек).

However, in pavian hamadryads these groupings consisted of waves whose frequency was at the lower end of the α-rhythm range, at 8 per second; in Cercopithecus callithricus the frequency was at the upper limits of the α-rhythm, at 12-13 per second (Fig. 2, D and E).

At the greater age of 6-8 months, the amplitude of all kinds of oscillation had fallen gradually. The amplitude of the slow waves varied from 50 to 200 μV, the waves of the α-rhythm from 50-150 μV, and the β-rhythm from 25 to 100 μv. There was a tendency for the high frequency components to be better shown, although the solitary slow waves were maintained. The principal rhythm was at 8-10 and 16-32 waves per second.

At the age of 2-2½ years, the EEG became stable and did not change until the age of 14-16 years. At this age the preponderant frequencies were the α- and β-rhythms and the amplitudes never exceeded 100 μV.

A certain number of slow waves at 4-6 per second were observed also in adult monkeys. At this age there was no difference in the electrical cortical activity of Cercopithecus callithricus and the other species (Fig. 3, A, B, and C).

Between 14 and 21 years in the pavian hamadryad and macaque rhesus the amplitude of all the waves fell still further, to reach the value of 10 to 60-80 μV (Fig. 3, D and E). Oscillations of the α- and β-rhythm types preponderated, and occasional slow waves at 4-6 per second having an amplitude of 50-60 μV were recorded.

The results we have described show that the electrical activity of the cerebral cortex of the lower monkeys in the first days of life is irregular, that the oscillations have various durations, and that the slow waves preponderate and increase considerably in the first month, reaching a maximum value at 6-8 months. Subsequently, the amplitude of the oscillations falls and becomes stable at an age of 2-2½ years, when there is a marked predominance of the higher frequency components of 8-12 and 16-32 waves per second. At greater ages the amplitude of all the waves is considerably reduced.

The results obtained for the macaque rhesus agree with those of other authors [10, 12].

The amplitude and frequency of the EEG rhythms of the Cercopithecus callithricus were always higher than those of the macaque rhesus and pavian hamadryads. The reason is perhaps related to metabolic features causing the higher potential values. The same sort of effect is found in the ECG when potentials from the heart are picked up. The voltage of the ECG waves in the Cercopithecus callithricus was greater than in the macaque rhesus and pavian hamadryads [5].

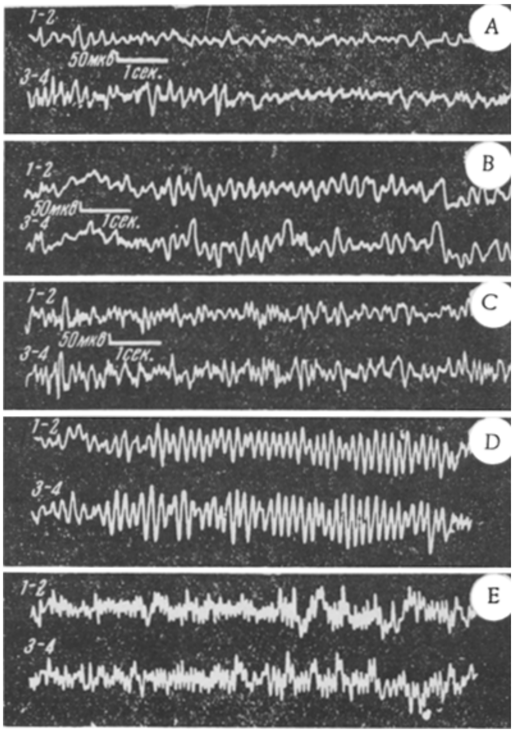

Fig. 2. EEG of a macaque rhesus (A), pavian hamadryad (B), and Cercopithecus callithricus (C) aged 1 month, and of a pavian hamadryad (D) and a Cercopithecus callithricus (E) aged 7 months.

Vertical scale(s) in millivolts (мв) or microvolts (мкв); horizontal scale(s) in seconds (сек).

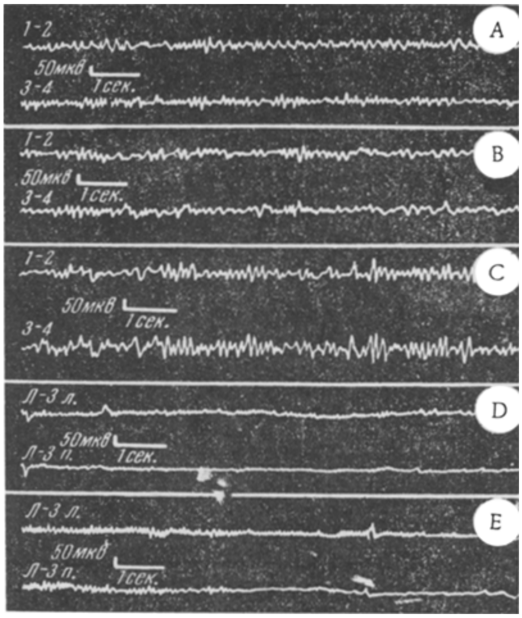

Fig. 3. EEG of a pavian hamadryad (A), a macaque rhesus (B), and a Cercopithecus callithricus (C) aged 2 years, and a macaque rhesus (D) and a pavian hamadryad (E) aged 21 years.

Vertical scale(s) in millivolts (мв) or microvolts (мкв); horizontal scale(s) in seconds (сек).

Published reports show that electrical activity is present in the cerebral cortex of rabbits [1, 2, 6], and of puppies [3, 7], and that it takes the form of irregular low amplitude waves, which are present even at the first day of life. In these animals the electrical activity characteristic of the adult EEG has developed completely by the age of one month.

The changes with age in the amplitude and frequency of the electrical oscillation of human and ape cerebral cortices show a great resemblance at these stages of development; however, they occur at different times. In childhood in both humans and apes the amplitude is low and the rhythm irregular. With age the voltage increases to a certain maximum; then it falls, and becomes stabilized. The greatest changes in the EEG of humans occur in the first year of life [11], while in apes they take place in the first month. Stabilization in the adult human takes place at the age of 12-15 years [4, 8, 9], and in apes at 2-2½ years; as in the human this change takes place before sexual maturity.

The age variations in the EEG cannot be related to changes in resistance associated with the formation of the skull bone and soft tissues, because similar EEG changes are found when the above potentials are led off directly from the brain surface [3].

Our own and published results show that the electrical activity of the cerebral cortex of animals at various levels of evolution pass through corresponding stages during the postnatal period. According to the stage of development of the central nervous system and its functional condition, the EEG of the lower animals such as rabbit and dog become stabilized at the end of the first month of life, whereas in the more highly organized apes stabilization occurs at 2-2½ years, and in man at 12-15 years.

Apparently the age changes of the EEG of the different animals reflect the degree of maturation of the different divisions of the brain. However, the mechanisms underlying this maturation are not well understood and require special study.

SUMMARY

Electrical activity was observed in the brains of lower monkeys – 20 pavian hamadryads, 20 Cercopithecus callithricus, and 31 macaque rhesus; during the first days of life there were irregular variations, and slow waves preponderated. By the age of 1 month there was a considerable increase in the potentials, which reached a maximum by 6-8 months. Later there was less variation, and stabilization occurred at 2-2.5 years, when the higher frequency components of 8-12 and 16-32 waves per second were prevalent. A distinct α-rhythm first appeared at the age of 4-6 months. In old age there was a further reduction in the amplitude of all EEG waves. From the first days of life and during the whole of the first year, distinct species differences appeared. In Cercopithecus callithricus the amplitude of the waves was greater and the higher frequencies were more distinct.

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