ELECTRICAL ACTIVITY AND CONSTANT POTENTIAL OF THE CEREBRAL CORTEX DURING SLEEP AND WAKING IN CHILDREN FROM THREE MONTHS TO ONE YEAR OF AGE

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The object of the present investigation was to study the electroencephalogram (EEG) and its constant component in children between three months and one year of age. The EEG was analyzed in different states, in children from the age of three months, taking place in the following order: sleep, active waking, a state associated with excitation of the food center, rest in a waking state after taking food, active waking associated with various movements and play activity, rest in a waking state changing to drowsiness and sleep.

In most investigations so far carried out, these states were not strictly distinguished, and this may have accounted for the inconsistency, and even the contradictory nature of the results published by different writers.

EXPERIMENTAL

Experiments were carried out on 78 normally developing, physiologically mature infants who were kept in a screened room.*

The EEG was recorded with bipolar leads from the projection area of the anterior central gyrus (frontal lobe), and the parietal and occipital lobes. The constant potential (the electronic state), was recorded by the method described previously [4].

For control purposes the action potentials of the facial muscles were recorded simultaneously with the EEG. A special graphic analysis was made of the EEG curves to determine the frequency distribution in different parts of the cerebral cortex by a method described fully elsewhere [3]. The state of waking, arising after taking food and lasting until it changed into a state of rest, and subsequent drowsiness was assessed chronometrically.

EXPERIMENTAL RESULTS

According to the results obtained, the children investigated could be divided into two groups: 1) children aged from 3-4 to 8 months, and 2) children aged from 8 months to one year.

In the children aged 3 months the first antigravity reaction had become finally stabilized, as shown by their ability to hold the head in the vertical position, and this was combined with unclasping of the hands, i.e., with disappearance of the flexor hypertonia in the upper limbs. As a result, movements of different kinds could be carried out with the hands and attempts could be made at play activity, which took place during the period of active waking arising after taking food. In the children aged 4 months the duration of the waking period was 46 ± 8 min, while in the children aged 5, 6, and 7 months it increased to 63 ± 6 min.

The characteristics of the EEG were similar during active waking associated with excitation of the food center and active waking after taking food. This was clear from the fact that in the parietal and occipital lobes (compared with the changes in these areas in children under 3 months of age) the number of slow waves gradually fell (2-3 cps) and the intensity of the fast waves increased (Fig. 1a). In these lobes the slow activity still persisted (4-5 cps), but at the same time rhythms with frequencies of 20-30 and

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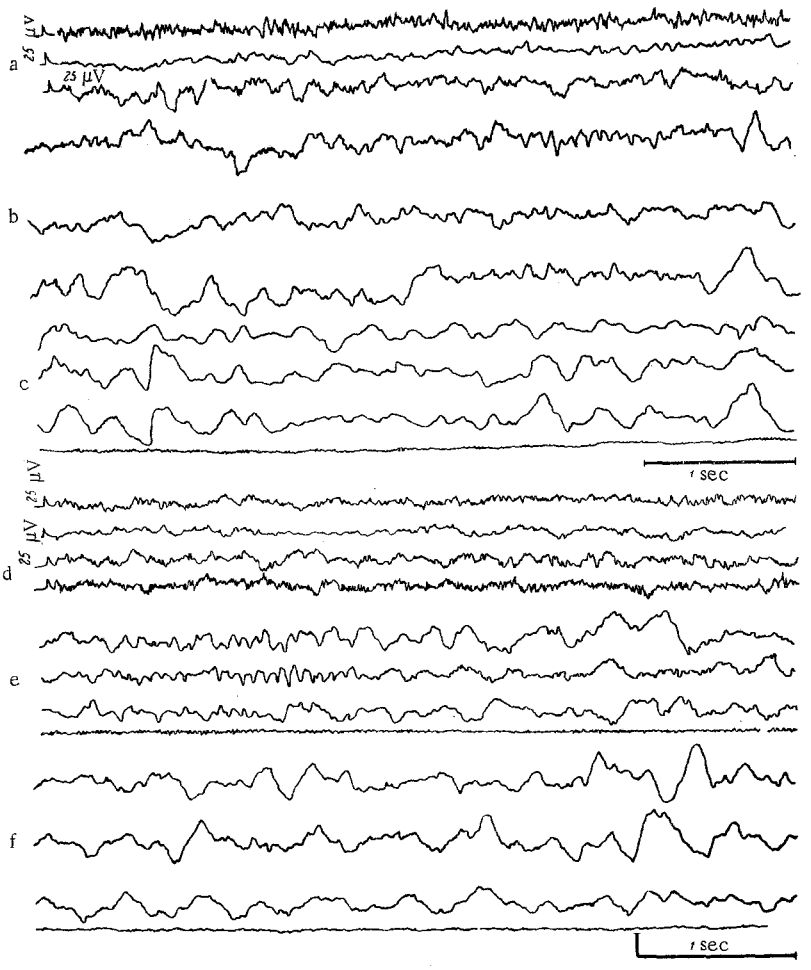

Fig. 1. EEG of children aged 4, 7, 8, 9, and 10 months. a) Child aged 4 months in a state of active waking; b) child aged 7 months in a state of waking rest; c) child aged 4 months in a state of sleep; d) aged 10 months in a state of active waking; e) child aged 9 months in a state of drowsiness; f) child aged 8 months in a state of sleep. From top to bottom: frontal, parietal, and occipital leads, action potentials from the facial muscles.

30-40 cps became more clearly defined than in children under 3 months of age. In the frontal lead rhythms with frequencies of 20-30 and, in particular, 30-40 cps continued to be recorded. Statistical analysis using the criterion of goodness of fit (χ^2) showed absence of agreement between the frequency compositions of the EEG of the frontal and occipital lobes. However, the probability of agreement increased to 0.35 by comparison with its value of 0.2 in children under 3 months of age. The probability of agreement between the bielectrical activity of the frontal and parietal lobes increased to 0.85 (in children under 3 months of age 0.75). The amplitude of the slow waves recorded in a state of active waking was 50-80 μV, and the amplitude of the fast waves was 7-20 μV.

In a resting state (waking rest) after eating and before going to sleep, slow waves (4-6 cps) began to predominate in all lobes, with fast waves, more marked in the frontal lead, superimposed on them. At this age for the first time a state of drowsiness appeared between waking and sleep, characterized not only by a more marked α-like rhythm in the parietal and frontal lobes, but also by the appearance of such a rhythm in the occipital lobe (Fig. 1b). This rhythm, however, had not yet the character of typical spindles. In a state of sleep, slow waves were recorded in all the leads, mainly with frequencies of 4-5 and 2-3 cps, with faster waves (9-11 cps) superimposed on them (Fig. 1c). The amplitude of the slow waves increased to 100-120 μV. Graphs showing typical features of the distribution of frequencies at this age in states of

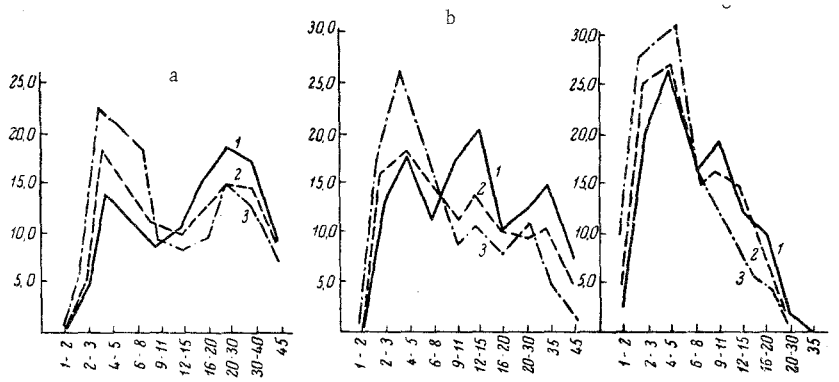

Fig. 2. Graphs showing distribution of frequencies in states of active waking, drowsiness, and sleep in the children of the second age group. a) State of active waking; b) drowsiness; c) sleep. 1) Frontal lead; 2) parietal lead; 3) occipital lead. Here and in Fig. 3: abscissa—frequency, ordinate—time occupied by waves of corresponding frequency, in percent.

active waking, drowsiness and rest, are given in Fig. 2. At this age the constant component of the EEG recorded in borderline states between waking activity and waking rest were characterized by electropositivity, with an amplitude of 2,8 ± 0.4 mV. In a state of sleep the amplitude of the electropositivity increased to 7 ± 0.6 mV.

In the children aged from 8 to 12 months inclusive, the duration of the period of active waking after taking food was still longer—120 ± 10 min. The increase in the duration of waking was connected with the fact that at the age of 8 months the sitting posture was finally stabilized and the child began to stand for the first time.

In the state of active waking, the slow waves persisted in the parietal and occipital leads (4-5 cps), but they were still more reduced than in the preceding age groups. Waves with frequencies of 20-30 and 30-40 cps were increasingly predominant. In the frontal lead the slow waves had almost completely disappeared and the dominant rhythms were 20-30 and 30-40 cps. As at the previous age, the amplitude of the waves with this frequency varied between 7 and 20 μV (Fig. 1d). Statistical analysis of the frequency composition of the EEG in the children of this age group using the χ^2 criterion, revealed a further increase in the probability of agreement: up to 0.40 when comparing the EEG of the frontal and occipital lobes and to 0.90 when comparing the EEG of the frontal and parietal lobes. The changes described are clearly shown on the frequency distribution graph (Fig. 3a).

In a state of waking rest, as in the children of the first group, a slower rhythm (4-6 cps), on which faster waves (20-30 and 30-40 cps) were superimposed, began to predominante on the EEG of all the lobes. The state of waking rest was not yet characterized by an α-rhythm, as in adults.

A marked α-like activity appeared in all the lobes, only in a state of drowsiness. However, as in the preceding age group, it had not yet acquired the character of typical spindles. With the change from waking rest to sleep, in the state of drowsiness, an analogy could be seen not only to the 3rd intermediate state (C), but also to a 4th or stage of moderately deep sleep (D), in which spindles and slow activity close to a δ-rhythm alternated successively (Fig. 1e). The clear presence of this stage in the state of drowsiness, shown by uniform changes in the electrical activity in all the lobes, can be seen in Fig. 3b. It was by the uniform change in the EEG in the state of drowsiness in all the lobes that the children of this age differed from those of the preceding age group. In the latter the changes in the EEG of different parts of the cortex in a state of drowsiness were still varied (Fig. 2b). In the children aged from 8 months to one year the analogy of state D, described above, gradually changed into stage E (deep sleep), characterized in adults by θ-waves. In the children of this age stage E was not yet identical with this stage in adults, for it was characterized not only by θ-waves, but also by δ-waves, on which waves with frequencies of 9-11 and 12-15 cps were superimposed, although fewer than in the children of the first group (see Figs 1f and 3c). The amplitude of the slow waves of δ-rhythm type now reached 120 or even 150 μV. This increase

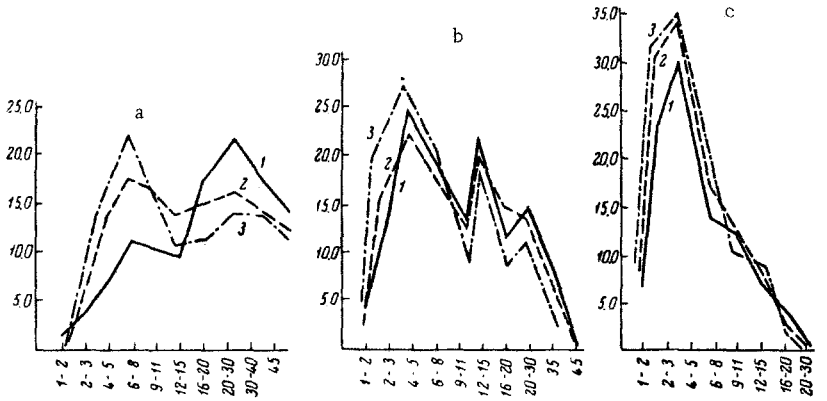

Fig. 3. Frequency distribution graph in a state of active waking, of drowsiness, and of sleep in children of the 3rd age group. a) State of active waking; b) drowsiness; c) sleep. 1) Frontal leads; 2) parietal; 3) occipital. Legend as in Fig. 2.

may be understood if the further changes in the constant component of the cerebral cortex are taken into consideration. In children aged 8-12 months, the electropositivity in the waking state was less marked than in the children of the preceding age group, amounting to 2 ± 0.8 mV. It had not yet acquired signs of electronegativity, as in adults. In the state of sleep the electropositivity showed a still further increase in amplitude by comparison with the children of the first group (8 ± 1.0 mV).

It may be concluded from the results of these investigations that the changes in the EEG patterns in children from the age of 3 months are characterized by the following features: the formation of a state of drowsiness with the gradual differentiation initially of a stage externally similar to C, and later of a stage externally similar to D; the formation of increasingly marked differences characterizing the EEG patterns in states of rest, active waking, and sleep, and by gradually increasing electropositivity during sleep, particularly marked in children after 8 months of age. The gradual appearance of the features is correlated with, and may even be dependent on, the organization of active waking arising after the child's regular meal, and the gradual increase in its duration.

Despite the increasing differences, the pattern of the EEG during waking still differed substantially from that in adults. It is evident that the more complex problem of the essential similarity between the slow activity of θ and δ type recorded in children under one year of age and in adults during sleep has not yet been satisfactorily solved. It must be emphasized that the problem is one of essential similarity, because laboratory investigations have shown that, unlike the sleep of adults, sleep in early age periods is an active state characterized by an increase in muscle tone and by high expenditure of energy per unit body mass [1, 2]. As Fig. 1 shows, constant tonic activity is found in particular in the facial muscles, not only during active waking but also in states of rest and sleep.

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