CHARACTERISTICS OF THE ELECTRICAL ACTIVITY AND THE CONSTANT POTENTIAL OF THE CEREBRAL CORTEX DURING SLEEP AND WAKING IN CHILDREN UNDER 3 MONTHS OF AGE

I. A. Arshavskii, M. N. Akhundi, and S. S. Solomatin

UDC 612.825.014.423.4:612.821.7]-053.31

Investigations carried out in the authors' laboratory have shown that in mammals (dogs, rabbits), the typical differences characterizing the individual pattern of electrical activity of the brain during waking and sleep in the adult organism do not develop in the process of postnatal ontogenesis until a certain age (after the appearance of the standing posture and organization of the resting state) [1-5,14]. Meanwhile, investigations of newborn children have shown that the characteristics of their electroencephalogram (EEG) distinguishing it from the EEG of young animals are not identical in the waking state (during regular excitation of the food center) and in the state of sleep arising soon after taking food [5].

There are reports in the literature that no difference exists between the EEG during sleep and waking [9,10, 24-28], and also others indicating the presence of differences [6,15-23,29].

Are the differences found in the sleep-waking cycle in newborn infants and children during the first weeks and months of life analogous to those observed in the adult person? This problem is extremely complicated and remains unsolved.

The object of the present investigation was to investigate the characteristics of the EEG in children during the first three months of life, differentiating strictly between the state of sleep and waking. The constant potential, i.e., the electrotonic state of the cerebral cortex, was also recorded.

EXPERIMENTAL METHOD

Bipolar recordings of the EEG were made in three leads: from the point of projection of the anterior central gyrus (subsequently called the frontal lobe) the parietal, and the occipital lobes of the cerebral cortex. The recording electrodes were silver disks 6 mm in diameter, fixed to the head by strips of adhesive plaster. Contact between the electrodes and the head was made by means of paste and a pad of gauze soaked in 2% NaCl solution. The distance between the electrodes was 1.0-1.5 cm. For control purposes, the electrical activity from the muscles of facial expression was also recorded. The cot containing the child was placed in a screened room. The EEG was recorded in an ink-writing electroencephalograph (Galileo). To record the changes in the electrotonic state of the cerebral cortex, the principle of modulation of the discreet recording of the constant potential through one of the channels was used, by means of a special adaptor described by K. K. Monakhov and V. I. Loginov [12]. The observations were made on 36 healthy, physiologically mature children aged between 20 days and 2.5-3 months.*

EXPERIMENTAL RESULTS

In the great majority of investigations of the EEG in young infants, no attention has been paid to the state of the child depending on the degree of its physiological maturity, or to whether the child is asleep or awake. The results of the present investigations demonstrated the need for distinguishing the following states: natural sleep arising after a full feed; active waking associated with regular excitation of the food center; waking rest, when the child lies with his eyes open and with minimal motor activity, and active waking, unconnected with excitation of the food center. In the present investigation, the duration of active waking developing after feeding was determined chronometrically. In children during the first 10-15 days of life this form of waking was absent; sleep developed

*The investigation was carried out at the Moscow Central Children's Home (Principal, E. V. Shulyat'eva).

Laboratory of Age Physiology and Pathology, Institute of Normal and Pathological Physiology of the Academy of Medical Science of the USSR, Moscow (Presented by Active Member of the Academy of Medical Sciences of the USSR V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 9, pp. 8-13, September, 1966. Original article submitted August 12, 1965.

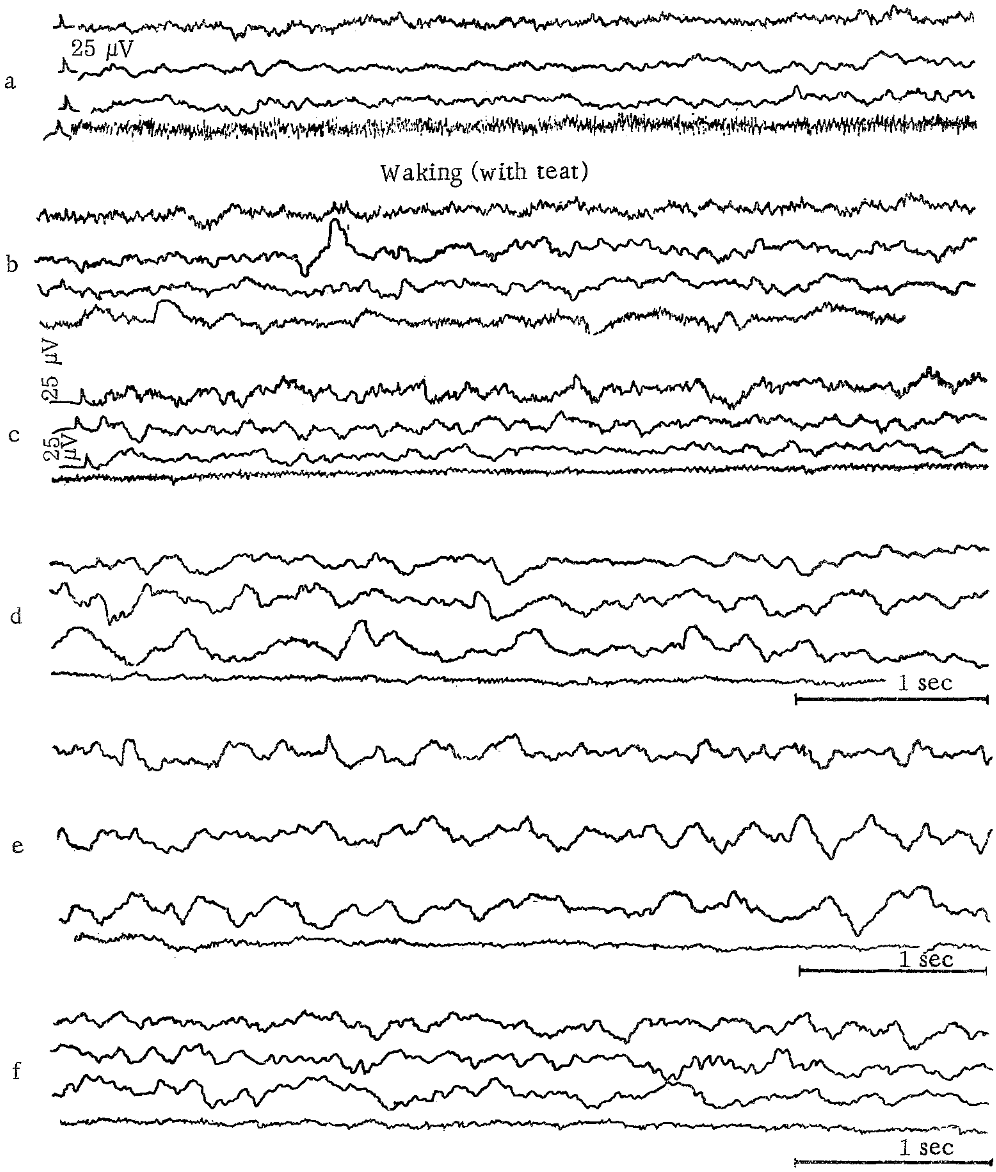

Fig. 1. EEG of children under 3 months of age: a) a child 20 days old in a state of active waking; b) a child aged 1 month when sucking a teat; c) a child aged 2 months before going to sleep (quiet waking); d) a child aged 1 month just going to sleep; e) a child aged 2 months in a state of sleep; f) a child aged 2 months in a state of drowsiness. From top to bottom: frontal, parietal, occipital leads, potentials from muscles of facial expression.

immediately after food was taken. To assess the topographical organization of the bioelectrical activity of different parts of the cortex and its variation with age, a graphic analysis was made of the distribution of frequencies in the EEG, i.e., the relative duration of particular waves was determined in the course of a unit of time and expressed in percent. This type of analysis has been described fully by I. A. Arshavskii and I. I. Gokhblit [4].

In children under 3 months of age the characteristics of the EEG during active waking differed from one area to another. In the frontal lobe, mainly high-frequency waves were present (16-20, 20-30, and 30-40/sec) superposed on slow rhythm (2-3 and 4-5/sec) of low amplitude (Fig. 1a). In the parietal lobe, slow activity was predominant (2-3 and 4-5/sec), on which ill-defined waves with frequencies of 16-20 and 20-30/sec were superposed. In the occipital lobe, slow activity of this frequency was more marked, while the fast activity was less marked. The amplitude of the slow waves was 35-45 μV, and of the fast 5-15 μV. The high-frequency activity was not the result of spreading of the action potentials from the muscles of facial expression. A parallel recording of the action potential from the muscles of facial expression revealed no similarity as regards frequency (the difference was almost 100%). The high-frequency activity in the frontal lobe, which could be recorded only after waking in association with regular excitation of the food center, also persisted if the child was given the teat of the feeding bottle, i.e., when sucking movements were carried out (Fig. 1b).

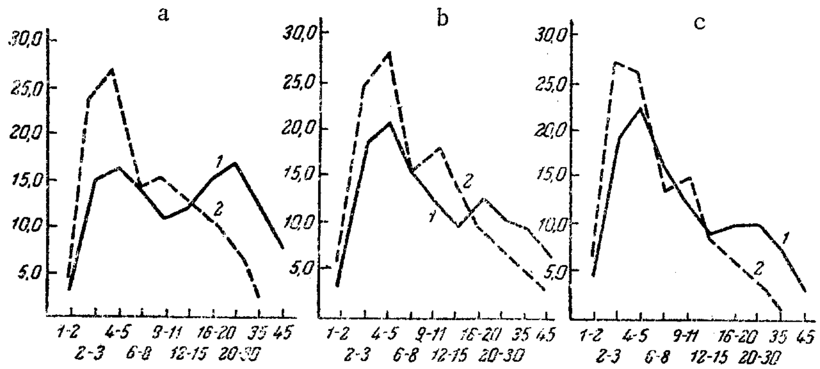

Fig. 2. Graph of distribution of frequencies in different areas of the brain in states of waking and sleep in children under 3 months of age: a) frontal lead; b) parietal; c) occipital; 1) waking; 2) sleep. Along the axis of abscissas — frequencies; along the axis of ordinates — distribution of frequencies (in percent).

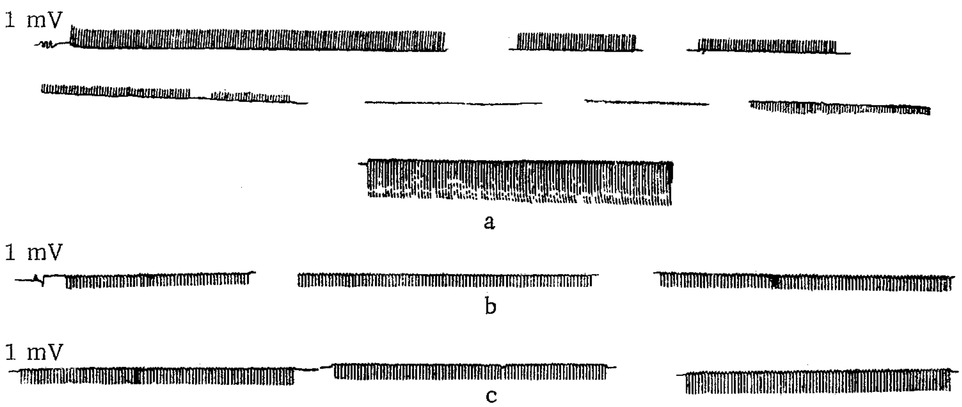

Fig. 3. Changes in the constant potential in states of waking and sleep: a) in an adult; b) in a child aged 1 month; c) in a child aged 2 months.

Hence, in early childhood, a state of active waking is revealed mainly in the EEG of the frontal lobe. Morphological maturation of the cells of the cortical ends of the motor analyzer is known to take place before maturation of the neurons of other areas [7,8,13]. Statistical analysis of the frequency composition of the EEG by Student's method, comparing the frontal and occipital lobes by the χ^2 criterion, revealed complete noncoincidence between them (probability of coincidence 0.20). The probability of coincidence during comparison of the frontal and parietal lobes was 0.75, indicating that the differences between them were smaller. The equally marked difference between the characteristics of the EEG of the various cortical areas during waking may naturally be explained by differences in the degree and rate of maturation of the cells in the different parts of the cortex.

In children under 1 month old, the high-frequency activity ceased to dominate the EEG after food had been taken and before going to sleep (quiet waking). In these circumstances slow activity began to predominate, and was more marked as the child was going to sleep (Fig. 1). In the frontal lobe, the high-frequency activity almost completely disappeared. In all the lobes a faster rhythm (9-11 and 12-15/sec) was superposed on the slow activity (2-3 and 4-5/sec). The amplitude of the slow waves increased during sleep to 80-100 μV. As Fig. 1e shows, the electrical activity of the muscles of facial expression persisted not only in a state of rest, but also during sleep.

At the age of 2.0-2.5 months, the slow activity became still more pronounced. The graphs of distribution of frequencies in the different parts of the cortex illustrated in Fig. 2 demonstrate the marked differences in the characteristics of the EEG in states of waking and sleep in children aged under 3 months. At the age of 2 months, in certain cases it can be seen that during the transition from waking rest to sleep, an α-like rhythm (12-15/sec) appeared for the first time, and was most prominent in the parietal lobe (Fig. 1f). This activity did not have the character of the typical spindles (a gradual increase in amplitude to a maximum followed by a decrease to the minimum). Before this age, no activity of α-type could be observed.

Under one month of age, sleep developed comparatively quickly after taking food without an intermediate C stage corresponding to drowsiness. Starting from 1, and especially 1.5 months, when the child first begins to raise his head into a vertical position, sleep no longer develops at once. It is preceded by waking, gradually becoming active in character. For instance, in children aged 1 month this form of waking lasted 13 ± 3.1 min, in children aged 2 months 18 ± 2.4 min, and by the age of 3 months it had increased to 34 ± 4.2 min. The electroencephalographic activity in this form of waking was closer to the electroencephalographic activity characteristic of regular excitation of the food center.

The characteristics of the constant potential may next be considered. As in adult dogs [1,2], in adult persons waking is characterized by electronegativity, with a mean value of 6 mV. In a state of rest or drowsiness, slight electropositivity (1-2 mV) may be recorded. The transition to sleep is characterized by a change from electronegativity to positivity, with a value of 8 mV or more. In children under 3 months of age, the state of active waking was characterized by electropositivity. Its mean value was 4.0 ± 0.2 mV. In a state of sleep, the positivity increased, but only very slightly, on the average of 6.2 ± 1.1 mV. The increase in the intensity of the anelectrotonic state, although only slight, explains the increase in amplitude of the slow wave during sleep by comparison with their amplitude in a state of waking. In Fig. 3, a tracing of the constant potential and of its changes depending on waking and sleep are demonstrated.

In children (in contrast to young animals), therefore, at a very early age marked differences may be seen in the electroencephalographic activity during the sleep-waking cycle. They differ significantly, however, from those in adults. Can it be concluded that the slow activity in a state of sleep in young infants is analogous to the "sleep potential" (Δ-rhythm), i.e., to the stage of sleep corresponding to stage E in adults? Additional study of this problem will be considered in the next paper by one of the authors of this article.

LITERATURE CITED

1. I. A. Arshavskii, Proceedings of a Scientific Conference in Memory of N. E. Vvedenskii [in Russian], Vologda (1960), p. 98.
2. I. A. Arshavskii, Abstracts of Proceedings of the Third Conference on Electrophysiology of the Nervous System [in Russian], Kiev (1960), p. 27.
3. I. A. Arshavskii, in the book: Structure and Function of Human Analyzers in Ontogenesis [in Russian], Moscow (1961), p. 65.
4. I. A. Arshavskii and I. I. Gokhblit, Fiziol. Zh. SSSR, No. 2, 181 (1965).
5. I. I. Gokhblit, Byul. éksp. biol., No. 8, 12 (1961).
6. L. G. Denisova and D. A. Farber, Abstracts of Proceedings of an All-Russian Congress of Children's Physicians [in Russian], Moscow (1959), p. 132.
7. L. A. Kukuev, Proceedings of the Second Scientific Conference on Age Morphology and Physiology [in Russian], Moscow (1955), p. 38.
8. V. N. Minaeva, Proceedings of the Second Scientific Conference on Age Morphology and Physiology [in Russian], Moscow (1959), p. 56.
9. N. S. Mirzoyants, Proceedings of the Third Scientific Conference on Age Morphology, Physiology, and Biochemistry [in Russian], Moscow (1959), p. 65.
10. N. S. Mirzoyants, Zh. vyssh. nerv. Deyat., No. 3, 432 (1961).
11. N. S. Mirzoyants, in the book: Electrophysiology of the Nervous System [in Russian], Rostov-on-Don (1963), p. 261.
12. K. K. Monakhov and V. I. Loginov, Byul. éksp. biol., No. 6, 96 (1962).
13. N. S. Preobrazhenskaya, Proceedings of the Second Scientific Conference on Age Morphology and Physiology [in Russian], Moscow (1955), p. 47.
14. V. D. Rozanova, Byul. éksp. biol., No. 6, 62 (1959).
15. F. N. Serkov and M. P. Dergileva, in the book: The Physiology of Nervous Processes [in Russian], Kiev (1955), p. 139.
16. D. A. Farber, Fiziol. Zh. SSSR, No. 6, 697 (1964).
17. A. N. Shepoval'nikov, Zh. vyssh. nerv. Deyat., No. 5, 797 (1962).
18. A. N. Shepoval'nikov, in the book: From the Simple to the Complex. Elements of the Development of the Higher Nervous Activity of the Child [in Russian], Moscow-Leningrad (1964), p. 27.
19. A. N. Shepoval'nikov, in the book: From the Simple to the Complex. Elements of the Development of the Higher Nervous Activity of the Child [in Russian], Moscow-Leningrad (1964), p. 44.

20. C. Dreyfus-Brisac,and C. Blanc, Encéphale, 45, 205 (1956).
21. C. Dreyfus-Brisac, World Neurol., 3, 5 (1962).
22. R. Ellingson, Electroenceph. clin. Neurophysiol., 10, 31 (1958).
23. R. Ellingson, Electroenceph. clin. Neurophysiol., 12, 663 (1960).
24. R. Frater and and G. Wohlmuth, Acta paediat. Acad. Sci. Hung., 1, 279 (1960).
25. R. Garsche, Biologische Daten für den Kinderarzt. Berlin, 2, 856 (1954).
26. R. Garsche, Z. Kinderheilk, 78, 458 (1956).
27. J. Hughes, B. Ehemann, and U. Brown, Am. J. Dis. Child., 76, 503 (1948).
28. J. Hughes, B. Ehemann, and F. Hill, Am. J. Dis. Child., 77, 310 (1949).
29. M. Sureau, H. Fischgold, and G. Capdevielle, Sem. Hop. Paris, 26, 2642 (1950).

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-tocover English translations appears at the back of the first issue of this year.