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# Peculiarities of the Pattern of EEG Activity in Institutionalized Children

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We studied the peculiarities of EEG activity in 25 institutionalized children (11 to 15 years old). The control group included 25 community children who were brought up in biological families; this group was identical to the main group in the number of tested persons and sex/age composition. In both groups of children, we recorded the EEG (10 leads) and estimated the level of anxiety using the Spielberger questionnaire and Prikhozhan's scale of personal anxiety. It was found that EEGs in institutionalized children were characterized, on average, by smaller values of spectral powers of the theta, alpha, beta1, and beta2 rhythms. Such differences in the EEG parameters were expressed to a greater extent in girls; this specificity could be related to the fact that the level of anxiety in institutionalized girls was significantly higher compared with the analogous index in control-group girls of the same age. We hypothesize that lower powers of most EEG rhythms in institutionalized children reflect, to a certain extent, a somewhat lower level of brain maturation and unbalanced functioning of the aminergic cerebral systems.

**Keywords:** EEG rhythms, spectral power, anxiety, institutionalized children.

## INTRODUCTION

In recent years, many researchers have investigated the peculiarities of development of institutionalized children (inmates of children's homes and boarding schools) [1, 2]. Most attention in this case has, however, been focused on the state of the psychoemotional sphere of such children. It should be noted that there are no children's homes and boarding schools in many countries with high levels of social and economic development. This is why examination of the development of orphan children is, in fact, geographically limited by the states of the former Soviet Union and socialist camp, as well as by some other countries having, as a rule, relatively low indices of social security and insufficient living standards [1, 3, 4].

It was demonstrated in some studies [5] that there is a complex of noticeable psychoemotional problems in orphan children who are permanent residents of specialized institutions; such problems are, first of all, related to the absence of normal child-parent relations. Since the state of the emotional and cognitive spheres of the personality is closely related to the functioning of the CNS, indices of electrical activity of the brain are actively used as objective correlates of the state of the mental and psychological sphere of the individual [6]. In investigations focused on typical peculiarities of the pattern of EEG in orphans, children younger than 8 years were usually involved [7, 8]. As far as we know, there is only one such study with the involvement of older institutionalized children (in the former Soviet Union, such studies have been carried out only in Kazakhstan [3]). Therefore, the peculiarities of crebral electrical activity in institutionalized children remain poorly investigated; this is why we concentrated our attention on this aspect.

## METHODS

In total, 50 children of two groups (main and control) were involved in our study. The main group included 25 children, permanent residents of the Simferopol' boarding school. The control group consisted of 25 children who were brought up in biological families; they studied at general educational schools of Simferopol'. Each group included 16 boys (11 to 15 years old) and 9 girls (11 to 14 years old). In the main and control groups, the mean age of boys was 160.4 ± 3.9 and 159.9 ±

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± 3.9 months, while the mean age of girls was 160.6 ± ± 4.6 and 160.0 ± 4.7 months, respectively.

Recording and analysis of EEG were carried out according to generally accepted techniques using a computerized set including an encephalograph (EEG-16S, Medicor, Hungary), a laboratory interface, and a computer. As a working program, EEG Mapping 3 (programmer E. N. Zinchenko) was used. EEG potentials were recorded monopolarly from frontal (F3, F4), central (C3, C4), parietal (P3, P4), temporal (T3, T4), and occipital (O1, O2) leads according to the 10-20 international system. As a reference electrode, joined contacts fixed above the mastoid processes were used. The cut-off frequencies of high- and low-frequency filters were 1.5 and 35 Hz, respectively; the digitization frequency of EEG signals was 250 $sec^{-1}$. The signals were processed using fast Fourier transform; smoothing was done according to the Blackman technique.

The background EEG activity was recorded in the state of motor rest with the eyes closed and open. The parameters of spectral composition of EEG for these two states were calculated separately. The analyzed segments were 60 to 75 sec long. As indices characterizing the spectral power of one EEG component or another, values of the square root of the density of distribution of the spectral power within the corresponding frequency range (spectral power density, SPD, μV/Hz) were calculated. In the EEG composition, the following ranges and subranges were differentiated: theta (4–8 Hz), alpha (8–13 Hz), alpha1 (8–9.5 Hz), alpha2 (9.5–11 Hz), alpha3 (11–13 Hz), beta1 (16–20 Hz), and beta2 (21–30 Hz). Modal frequencies of the alpha subranges were measured as the mean frequency of the respective subcomponent demonstrating the maximum amplitude in 20-25 2.56-sec-long segments of recording. We also calculated the ratios of the SPDs of the following ranges and subranges, alpha vs. theta, beta1 vs. theta, and beta2 vs. theta.

The levels of anxiety were estimated using the Spielberg–Khanin test [9] and Prikhozhan's scale of personal anxiety [1]. The latter allowed us to estimate different aspects of anxiety (school, self-appraisal, interpersonal, and "magic") and the index of the total anxiety level.

Numerical data of the electrophysiological study and indices of psychological tests were quantitatively treated using standard techniques of variational statistics. Depending on the type of distributions of the indices, we used the parametric Student's test or non-parametric Mann–Whitney test.

## RESULTS

The results of psychological testing showed that the level of personal anxiety in institutionalized girls estimated by the Spielberger test was significantly higher than in girls of the same age of the control group (46.7 ± 2.0 and 39.1 ± 2.0 points, respectively; $P < 0.05$). Differences in the indices of anxiety in girls of the above-mentioned groups, when determined using other scales, did not reach the significance level. Between boys of the control and main groups, there were no significant differences in the levels of anxiety, although some trend toward higher values of these indices could be noticed in institutionalized persons. According to the Spielberger test, levels of personal anxiety in boys of the main and control groups were 42.1 ± ± 1.8 and 41.0 ± 2.1 points, respectively ($P > 0.05$). Based on these results, encephalographic studies for groups of girls and boys were carried out separately.

In EEG samples recorded with the eyes closed, girls of both groups demonstrated significant differences in the spectral power of the theta rhythm. This index in institutionalized girls was smaller in practically all leads (in F4, C3, C4, P3, and O2, $P < 0.05$, while in T3, T4, and P4, $P < 0.01$). In girls of the main group, the mean spectral powers of the alpha rhythm were also lower in general (in F4, C3, and O1, $P < 0.05$, while in T3 and O2, $P < 0.01$). The spectral powers of subranges of this rhythm, namely those of the alpha1 rhythm, were smaller in F4, T3, C3, P3, and O2 ($P < 0.05$) and in T4 ($P < 0.01$). The powers of the alpha2 rhythm were lower in F4, T3, T4, and O1 ($P < 0.05$) and in O2 ($P < 0.01$). The same was true for alpha3 oscillations (in F3, C3, C4, P3, and P4, $P < 0.05$, and in F4, T3, T4, O1, and O2, $P < 0.01$). In practically all leads in the examined girls of the main group, we also found smaller values of the mean spectral powers of the beta1 and beta2 rhythms, as compared with the corresponding powers in children of the control group (beta1, in T4 and P3, $P < 0.05$, in F4, T3, C3, C4, and O1, $P < 0.01$, in P4 and O2, $P < 0.001$; beta2, in T3, C4, P3, O1, and O2, $P < 0.05$, in F4, T4, C3, and P4, $P < 0.01$).

Significant intergroup differences in the modal frequencies of alpha oscillations were observed only in one case, namely in girls of the main group. This index for alpha1 oscillations in lead O2 was smaller than that in girls of the control group ($P < 0.05$).

The ratios between powers of the alpha vs. theta and beta1 vs. theta rhythms in institutionalized

girls were smaller than those in the control group; however, only differences in the alpha vs. theta ratio in lead O2 reached the significance level ($P < 0.01$).

The results of comparison of EEG samples recorded with the eyes open in girls of the examined groups were as follows. In practically all leads in the main group, we observed significantly smaller values of the spectral powers of theta, alpha, beta1, and beta2 oscillations (Fig. 1). Powers of the subranges of the alpha rhythm in girls of the main group also were lower than the analogous indices in the examined persons of the control group. The mean power of the alpha1 rhythm was smaller in leads C3, C4, P4, and O2 ($P < 0.05$), T3, T4, and P3 ($P < 0.01$); the power of the alpha2 rhythm was significantly lower in leads F4, T3, C3, P3, P4, O1, and O2 ($P < 0.05$) and T4 ($P < 0.01$), while the power of the alpha3 rhythm was significantly lower in leads F4, C3, and C4 ($P < 0.05$), T3, T4, P4, and O2 ($P < 0.01$); in lead O1, the value of $P$ was less than 0.001.

In all leads, the modal frequency of the alpha rhythm in girls of the control group was higher than that in institutionalized girls; however, these differences did not reach the significance level. The modal frequency of the alpha1 subrange in girls of

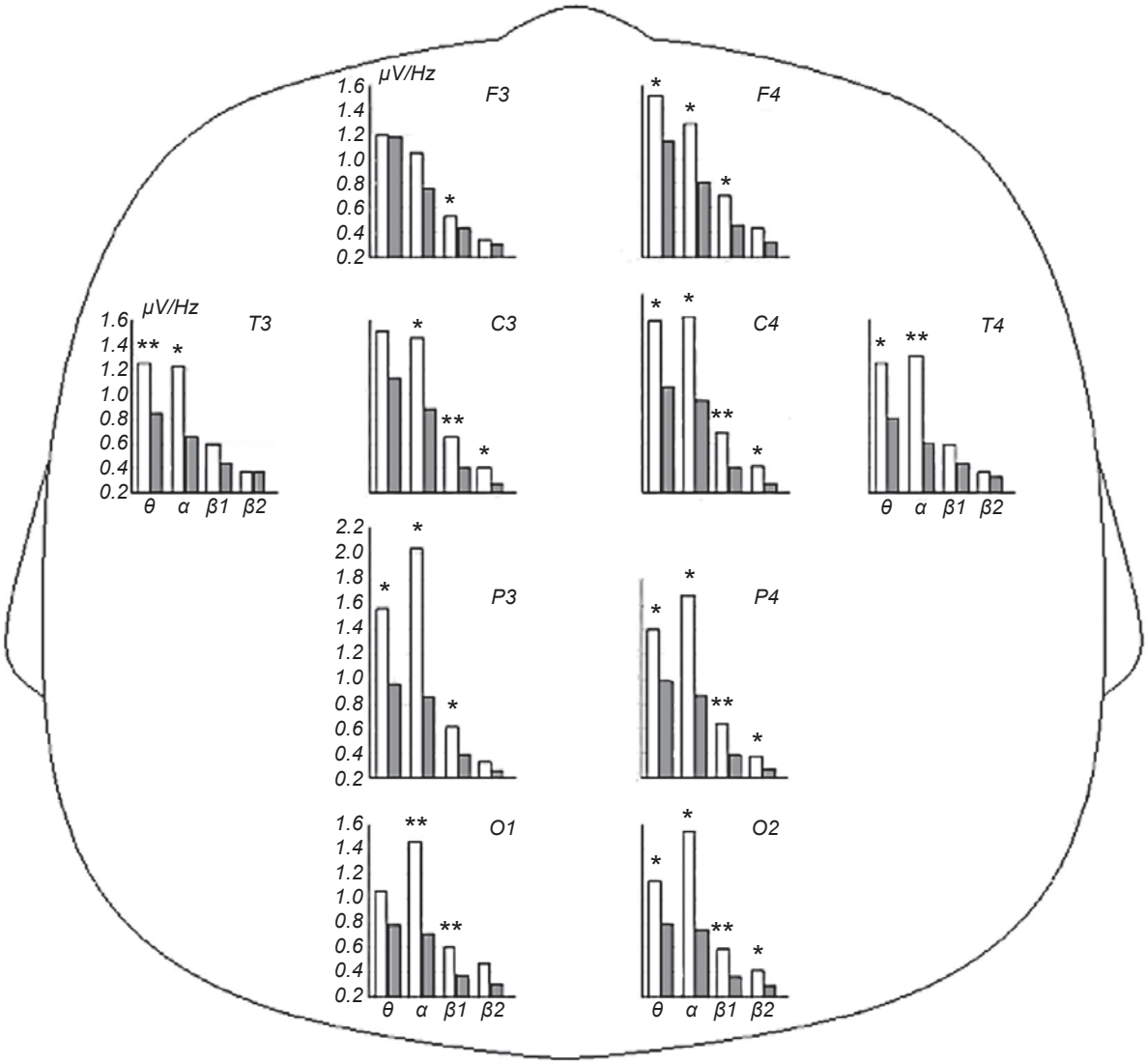


**Fig. 1.** Diagrams of the mean values of the spectral power density (SPD) of the EEG rhythms in girls of the control (open columns) and main (gray columns) groups; EEG was recorded with the eyes open. Horizontal scale) EEG rhythms; vertical scale) values of SPD, μV/Hz. One and two asterisks show cases of significant intergroup differences ($P < 0.05$ and $P < 0.01$, respectively). F3, F4, T3, T4, C3, C4, P3, P4, O1, and O2) EEG leads according to the 10-20 international system. In both groups, $n = 9$.

the control group was also higher than that in persons of the main group; these differences in lead P3 were significant ($P < 0.05$). Higher values of the modal frequency of the alpha2 rhythm were also typical of persons of the control group, but this was only a trend. As to the modal frequency of the alpha3 subrhythm, this index was somewhat higher in all leads in girls of the main group; in lead O1, these differences reached the significance level ($P < 0.05$).

In girls of the main group, ratios of the spectral powers were lower for alpha vs. theta (in F3, T4, O1, and O2, $P < 0.05$), alpha2 vs. theta (in O2, $P < 0.05$, and in T4, $P < 0.01$), and alpha3 vs. theta rhythms (in O1, $P < 0.05$). In institutionalized girls, the ratios between the powers of alpha1 and theta rhythms, as well as beta1 vs. theta rhythms, were also smaller compared with those in girls of the control group, but these differences were insignificant. In the majority of leads, the value of powers of beta2 and theta rhythms was higher, but insignificantly. In girls of the control group; however, this ratio in lead T3 was higher in girls of the main group ($P < 0.01$).

Between both groups of girls, significant differences in indices of interhemisphere asymmetry of the alpha range and its subranges with eyes both closed and open were not found.

A comparison of the EEG parameters in boys of the control and main groups showed the following. In institutionalized boys, EEGs with the eyes closed were characterized on the whole by lower values of the mean powers of the theta and alpha rhythms and modal frequency of the alpha rhythm, compared with the analogous indices in children of the control group; these differences were, nonetheless, statistically insignificant. As to the power and modal frequency of the alpha1 subrange and the power of oscillations of the alpha2 subrange, differences between the two groups were also insignificant; in most cases, these indices were higher in boys of the control group. In all leads, the modal frequency of the alpha2 rhythm in institutionalized boys was lower than the analogous index in boys of the control group; however, the above differences were significant only in the parietal zones ($P < 0.05$). The power of the alpha3 rhythm in boys of the main group also was, on average, lower than that in boys of the control group (in T3, T4, C3, C4, and O2, $P < 0.05$, while in O1, $P < 0.01$). As to the modal frequency of the alpha3 rhythm, this was higher in most leads in institutionalized children than that in boys of the control group; however, the differences did not reach the significance level. In boys of the main group, mean powers of the beta1 and beta2 rhythms were also lower; however, the respective differences were insignificant.

Institutionalized boys were characterized by greater, on average, ratios of the powers of the alpha1 and theta rhythms, as compared with the analogous indices in children of the control group; in the left parietal region, such difference reached the level of significance ($P < 0.05$). In addition, we found a noticeable trend toward higher values of the ratio of the alpha2 vs. theta power in children of the main group; however, these differences were insignificant. The mean ratios of the powers of the alpha3 and theta rhythms in institutionalized children in all leads were lower than those in boys of the control group, but the differences were below the significance level. Ratios of the powers of the beta1 and theta rhythms, as well as those of the beta2 and theta rhythms, were greater in boys of the main group, but differences also did not reach the level of significance.

The parameters of the EEG samples recorded in boys with the eyes open demonstrated the following intergroup differences. In the main group, the powers of oscillations of the theta and alpha rhythms in all EEG leads were lower compared with the values of these indices in boys of the control group; for the theta rhythm, these differences reached the significance level in lead T3 ($P < 0.05$), while differences for the alpha rhythm were significant in leads T3 and O1 ($P < 0.05$) (Fig. 2). The mean spectral powers of beta1 and beta2 oscillations were also smaller in boys of the main group than those in boys of the control group, but the differences were below the significance level.

Powers of the alpha1, alpha2, and alpha3 subrhythms in institutionalized boys were lower, but the differences reached the significance level only for oscillations of the alpha2 and alpha3 subranges in lead O1 ($P < 0.05$). The modal frequency of the alpha rhythm was also lower in boys of the main group, but the differences were insignificant. The modal frequencies of the alpha1 and alpha3 rhythms were higher in children of the main group, while the modal frequency of the alpha2 rhythm was higher in boys of the control group; these differences were also manifested only as trends and did not reach the significance level.

In institutionalized boys, ratios of the powers of the alpha1 and theta rhythms, as well those of the alpha2 vs. theta rhythms, exceeded the respective figures in boys of the control group; at the same time,

ratios of the powers of the alpha3 and theta rhythms were, on average, smaller; these differences were below the significance level. In boys of the main group, ratios of the powers of the beta1 vs. theta rhythms, as well as those for the beta2 and theta rhythms, were greater in all leads; as to the former index, these differences exceeded the significance level in leads T3 ($P < 0.01$) and O1 ($P < 0.05$), while the latter parameter was greater in leads T3 ($P < 0.01$), T4, and O1 ($P < 0.05$).

We observed no significant differences between indices of interhemisphere asymmetry of the alpha range and its subranges with the eyes both closed and open in boys of the two examined groups.

## DISCUSSION

Our study demonstrated that institutionalized children differ from children of the control group in lower mean spectral powers of practically all EEG rhythms. The appreciably greater number of significant differences in the indices of EEG activity observed in girls of the main and control groups deserves special attention. In institutionalized boys, the EEG indices differed from those in the control group to a lesser extent; in most cases, the differences were obvious but did not reach the significance level. Such peculiarities can be related to the fact that significant differences in the levels

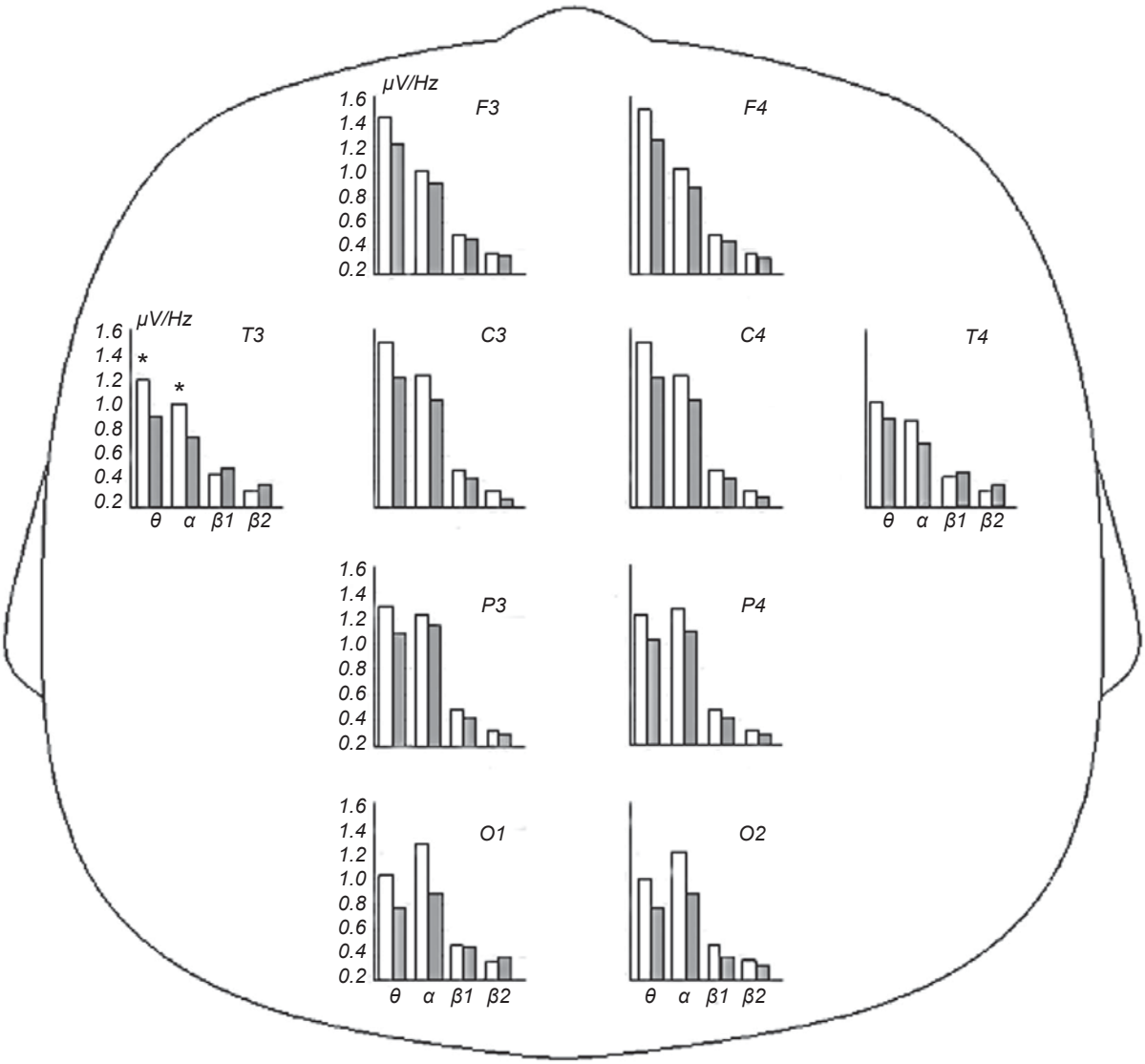


**Fig. 2.** Diagrams of the mean values of the spectral power density of the EEG rhythms in boys of the control (open columns) and main (gray columns) groups; EEG was recorded with the eyes open. In both groups, $n = 17$. Designations are the same as in Fig. 1.

of personal alertness were more clearly manifested precisely in girls of the examined groups; we believe that this was the main factor determining the presence of more clearly expressed differences in the EEG indices. Dobrova-Krol [5] examined preschoolers in Ukraine and found that children who were brought up in children's homes are characterized by higher levels of cortisol. This fact indicates that orphan children are permanently in a certain background stress state. In the cited study, clear sex-dependent differences were not observed in such vulnerable children. One more examination [3] showed that the level of personal anxiety, when determined according to the Spielberger test, in 11- to 12-year-old institutionalized children, brought up in an orphan home in Kazakhstan, significantly exceeded the analogous levels in children who were brought up in biological families. In this case, the level of anxiety was also estimated for a combined group of boys and girls.

Based on our data, we hypothesize that girls of prepubertal and pubertal age educated in a specialized institution under conditions of the absence of normal child-parent relations are characterized by a higher level of emotional tension and a higher level of anxiety than the respective boys. It is natural that the obtained facts should be interpreted with certain reservations. A possible effect of limited composition of the examined groups cannot be ruled out since it is known that the data obtained on small samplings can only partly correspond to the findings obtained on samplings with a greater number of examined persons. At the same time, it is obvious that rather clear intergroup differences in many EEG indices are readily manifested even in the case where the number of the tested children was rather limited.

In our recent studies with examination of 10- to 15-year-old persons who were brought up in biological families [10, 11], we found that highly-anxious individuals are usually characterized by decreased values of the powers of the theta and beta2 rhythms. The EEG studies of institutionalized babies and preschool children carried out in Romania [4] showed that greater powers of the theta rhythm and lower powers of alpha and beta oscillations are typical of these children, compared with analogous indices in community children. This fact has been considered a manifestation of some delay in maturation and development of the CNS and/or insufficient activity of the cerebral cortex.

The fact that both the spectral power of the alpha rhythm on the whole and the powers of its subranges were lower in institutionalized children of the main group, compared with the control group, attracts special interest. It is believed [12, 13] that, in the course of performance of different tasks, the level of desynchronization of EEG oscillations of the alpha1 subrange is related to activation of the system of mental alertness, that of the alpha2 subrange, to intensification of the processes of expectation/preparation for the action, while that of alpha3 oscillations is related to the process of recall and estimation/processing of incoming information. The decrease in the intensity of EEG desynchronization within the given frequency band and the ability to adequately perform the task coincide with the decrease in the expression of the alpha rhythm in the relatively resting state. The decreased power of the alpha rhythm in children of the main group found in our study can be indicative of some limitation of their cerebral resources providing the cognitive potential. Decreased expression of the alpha1 rhythm can also be related to excessive alertness in these children.

It is known that individual typological personality traits and peculiarities of the pattern of EEG activity are closely related to the specificity of functioning of the cerebral aminergic systems [14, 15]. In studies on animals, the crucial effect of early-life experience on the development of these cerebral systems was noted [16]. We hypothesize that the decreased powers of practically all EEG rhythms in institutionalized children reflect a somewhat lower level of maturation and imbalanced functioning of the brainstem aminergic structures, compared with that observed in community children.

It should probably be emphasized that clear differences between the patterns of background EEG in institutionalized and community children were found in the course of comparison of the groups, which were rather limited from the quantitative aspect. Our own results show that maximum effort should be applied to activate the work of specialized child institutions, in particular to limit the factors negatively influencing the development of the CNS and to decrease stress-induced anxiety in institutionalized children.

In institutionalized children, testing and EEG recording were performed with the official permission of the Ministry of Public Health of the Autonomic Republic of Crimea and managers of the Simferopol' Special Comprehensive Boarding School No. 1 of I-II degrees, as well with the personal consent of all the children. Community children

were involved in the tests with consent of their parents who were informed about the examination procedures in detail, as well as with the personal consent of the children. Our study was carried out in accordance with ethical principles of the Helsinki Accord (1964) and approved by the Ethics Committee of the Vernadskii Tavricheskii National University, Simferopol', Autonomic Republic of Crimea, Ukraine.

The authors of this study, E. V. Éismont, O. V. Pritchenko, and V. B. Pavlenko, confirm that they have no conflict of interest.

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