
It is known that the ontogenetic formation of mental functions is intimately associated with the rates of the maturation of brain structures. A delay in this process leads to disorders in cognitive activity and learning problems in junior schoolchildren [1–4]. In this connection, the study of brain structures in children with learning problems is an urgent scientific problem. Two complementary approaches to this problem are known. One of them is based on the structural analysis of an EEG and the identification of specific patterns considered as markers of the brain state, first of all, the regulatory brain structures. This concerns children with learning problems, mental retardation, etc. [3, 5–8]. The second approach is based on the study of a spatiotemporal organization of the brain electrical activity as a biopotential field [9]. This approach requires the application of spectral–correlation techniques and methods of multivariate statistics. In particular, the application of such an approach in longitudinal studies [10] made it possible to show that a delay in the maturation of brain structures is the chief cause of learning problems. However, despite the variety of approaches and ever-growing interest in this problem, many topical questions remain. One of them is the question of the manner in which the retardation of the maturation of brain structures declares itself in different developmental periods.

The aim of this study was a comparative analysis of spectral EEG characteristics of mentally healthy children and children with learning problems of the junior school age (7–8.5 and 8.5–10 years) at rest and during performance of a Raven test.

METHODS

Two age groups (7–8.5 and 8.5–10 years) of junior schoolchildren with learning problems (21 and 20 children, respectively) and mentally healthy children of the same age (12 and 15 children, respectively) were examined. They all were right-handed, and boys and girls were approximately equally represented in the groups. The clinical examination included the following procedures: (i) the history of perinatal development, (ii) analysis of the results of a prophylactic medical examination, (iii) a neurological examination, and (iv) an assessment of the presence and extent of neurotic and neurosis-like reactions (headaches, sleep and appetite disorders, undue fatigability, etc.). The psychological testing included an evaluation of the following: (i) verbal intelligence using a revised Amthauer test; (ii) nonverbal intelligence by a Wechsler Scale; (iii) characteristics of complex forms of perceptive activity and nonverbal thinking by Raven Progressive Matrices; (iv) predictive activity by Peresleni’s technique; (v) features of visual perception, spatial orientation, visuomotor coordination, and intermodal integration by the Bender visuomotor Gestalt Test. All the groups of children were also characterized by an anal-
ythesis of their current academic progress and their teacher’s opinion.

Scales of the Raven Progressive Matrices were used as test tasks. A variant for children was used. It included three task series: A (to identify the missing part of the control structure on the basis of its comparison to samples); AB (to reveal the principle of construction and to find the missing fragment of the control figure by analogy); and B (after the algorithm associated with a complication of figures with new elements, a child had to find the missing fragments of the control figure). These tests were used, because, in the opinion of some authors [11, 12], image thinking plays a leading part in the cognitive activity of children at this age and visual and motor coordination is the most important function, which is the basis for the development of the cognitive and graphic skills necessary for mastering reading and writing [12].

During the examination, a child comfortably sat in an armchair in a shielded, darkened room. The monopolar EEG was recorded at rest (with open and closed eyes) and during the performance of tasks from symmetrical frontal (F3, F4), temporal (T3, T4), central (C3, C4), parietal (P3, P4), and occipital (O1, O2) areas in reference to coupled earlobe electrodes (the International 10–20 System) in the frequency range of 0.03–60 Hz. In parallel, the oculogram was recorded. Analog signals were sampled at the rate of 200 Hz and fed into a computer.

After digital low-frequency (below 0.8 Hz) filtering, the EEGs of each child were examined by two independent experts and 30–60 artifact-free, 1.28-s fragments were selected in each experimental condition for analysis. Fast Fourier Transform was used for the calculation of the EEG mean spectral power (MSP) in the frequency ranges of the α1 (7.80–10.14 Hz), α2 (10.92–13.26 Hz), β1 (14.04–17.94 Hz), and β2 (18.72–30.42 Hz) rhythms with a frequency step of 0.78 Hz. For a better approach to normal distribution, the obtained data were subjected to log-transformation and were statistically estimated by a multifactor analysis of variance (ANOVA) [13]. When the groups of children were compared, the following factors were tested: Group (G) (two levels: children with learning problems versus children of the control groups); Rhythm (R) (six levels corresponding to the α1, α2, β1, and β2 EEG rhythms); and Lead (L) (ten levels corresponding to F3, F4, T3, T4, C3, C4, P3, P4, O1, and O2). When comparing states within each group, the following factors were tested: Condition (C) (the state of rest with open eye versus performance of Raven test), rhythms, and leads. Repeated measure and simple design procedures were applied. The difference was considered statistically significant at the level of p ≤ 0.05. At 0.05 ≤ p ≤ 0.1, the difference was considered to be at the level of a strong trend [14].

RESULTS

Results of psychological and clinical examination. Among children with learning disabilities, 83% had a history of complications of perinatal and early postnatal periods (birth trauma, thresus incompatibility, asphyxia, toxicosis of pregnancy, viral and bacterial infections, etc.). Neurological examination did not reveal gross lesions of brain structures, however, light neurological symptomatology indicated residual organic lesions of the CNS. More or less evident psychorganic syndrome (its asthenic variant) was observed in 78% of children (increased fatigability and distractibility, behavioral instability, etc.).

Psychological examination of children with learning problems revealed a decrease in the span of voluntary attention and its stability, and high distractibility as well. They successfully performed only 33.6% and 43.6% of tasks for voluntary attention (7- to 8.5-year-old and 8.5- to 10-year-old children, respectively), whereas mentally healthy children of the same age performed 69.8 and 80.1% of the tasks, respectively. Also, a deficit of involuntary forms of attention was revealed in 7- to 8.5-year-old children with learning problems: they performed only 38.5% of the respective tests, whereas the control group of the same age performed 81.5% of these tasks. In older children with learning problems, these indices were significantly higher (70.2%) and approximated to those of children of the control group (91.3%). In addition, in all the children with learning problems, spatial orientation and sensorimotor coordination were markedly impaired, which substantially affected the efficiency of complex forms of perceptive activity. Analysis of thinking structure of these children revealed the predominance of nonverbal intelligence over its verbal form. The main causes of the decrease in verbal intelligence were problems in the formation of new concepts and limited vocabulary.

Children with learning problems at the age of 7–8.5 years successfully performed, on average, 49.1% of the tasks of the Raven test, and 8-5- to 10-year-old children coped with 67.0% of these tasks. Children of the control groups successfully performed 81.8 and 91.1% of tasks, respectively. The tasks of series A were rather successfully performed both by children of the control groups (87.2 and 98.1%, respectively) and by children with learning problems of the same age (72.5 and 85.1%, respectively). In series B, children with learning disabilities solved successfully only 30.2% of tasks at the age of 7–8.5 years, and older children (8.5–10 years) coped with 50.7% of the tasks. Age-matched controls successfully performed 70.2 and 76.1% of tasks, respectively. The obtained evidence suggests the persistence of simple forms of perceptive activity (such as visual perception of images with one leading character, visual recognition and classification of simple elements, and completion of matrices in cases when operations of analytical perception are not required) in children with learning problems and substantial delay in