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Evaluation of Psychomotor Coordination during Educational Activities in Adolescents with Mental Disorders in Remission †

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Abstract: The imbalance between the speed and accuracy of cognitive–motor operations can lead to the formation of abnormal behavioral programs fraught with serious negative consequences for the individual. For successful correction and prevention of social disadaptation in adolescents with nervous and mental diseases and functional disorders in the mental sphere in general education schools, the peculiarities of their psychomotor activity should be taken into account. We measured some parameters of visual–motor coordination and sensorimotor reaction in adolescents with mental disorders with or without organic brain damage. Adolescents from both groups showed higher speed, but poorer accuracy and smoothness of movements than typically developing students. The visual and acoustic reaction times were longer in adolescents with mental disorders without organic brain damage than in reference groups.

Keywords: psychomotor tests; mental disorders; adolescents; educational process; monitoring

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1. Introduction

Adolescents defined by the United Nations as those between the ages of 10 and 19 make up 1.2 billion of the world's population today. According to UNICEF analysis based on estimates from the Institute for Health Metrics and Evaluation (IHME) [1], mental health conditions constitute a major burden of disease for adolescents globally. Epidemiological studies show that one in seven young people nowadays meet the criteria for a mental disorder [2–4]. Many adolescents with mental health problems study in mainstream schools as part of an inclusive education system, which can be considered a promising model for reducing their stigmatization and integrating them into society. Taking into account the neuropsychic characteristics of schoolchildren with mental disorders, the school needs fairly easy-to-use methods for express diagnostics of the functional state of such students. However, schoolchildren with peculiarities of neuropsychiatric features need close monitoring of their functional state as psychological and pedagogical support in the course of educational activities. One of the indicators that is quite easy to control in school life is psychomotor activity. Changes at all levels of organization of motor acts (sensory input, neural networks, muscle reaction) can affect the behavior of an individual. Motor disturbances have been demonstrated for a number of mental disorders, even in cases when they are not among the main diagnostic (clinical) symptoms of the disease [5,6]. On the other hand, it is believed that motor dysfunctions can appear at the early stages of ontogeny in individuals who later develop a psychopathology, in particular, psychotic reactions, and can represent a premorbid characteristic of these states [7,8]. However, the development of motor skills is a dynamic process. In childhood, motor skills rapidly progress and motor deficits in children with neuropsychic problems are quite noticeable. In adolescence, the development of motor skills is decelerated, which can mask deviations in the rate of maturation of the neuromotor circuits in adolescents with mental disorders, who do not differ from children with typical development by many parameters of fine motor skills and coordination [9]. However, motor deficits can manifest themselves when performing tests associated with high speed and accuracy of execution, with quick switching of attention, etc. Impairments in sensorimotor reactivity and psychomotor coordination can be caused by damage to the areas of the brain involved in the planning and organization of behavior, or by changes in the connections between them [10]. For assessing physiological and mental functions of students under conditions of educational institutions, the use of relatively simple methods for monitoring their functional state is advisable [11]. **Our objective** was to study the features of psychomotor coordination in adolescents with neurodevelopmental disorders by using simple motor tests.

2. Materials and Methods

Participants. The study included data obtained in the course of sanogenetic monitoring of the health status of students aged 11–18 years in educational institutions. Monitoring was carried out as part of the municipal program for the development of technology for express assessment of public health based on a comprehensive multisystem survey [12], including, among other indicators, an assessment of the state of psychomotor systems. Adolescents from a specialized school for patients of psychiatric clinics at the stage of remission, as well as students referred by a psychoneurologist as in need of psychological and pedagogical rehabilitation formed a group "Mental Disorders" (MD, n = 63). Based on medical records only, the participants from this school were divided into two groups: adolescents with a history of organic (O) brain pathology, and adolescents with mental disorders without organic (WO) brain pathology. The control groups included typically developing (TD, n = 70) students of general education schools of the same age. For data analysis, the groups were divided into two age ranges. The gender and age characteristics of the examined samples are presented in Table 1.

Table 1. Gender and age characteristics of adolescents in the examined groups.

Group	Typical Development				Mental Disorders							
					Without Organic Pathology of the Brain				With Organic Pathology of the Brain			
Sex	Female		Male		Female		Male		Female		Male	
Age	11–14.6	14.7–18	11–14.6	14.7–18	11–14.6	14.7–18	11–14.6	14.7–18	11–14.6	14.7–18	11–14.6	14.7–18
n	8	24	14	24	3	8	4	12	3	4	7	22
ICD-10 codes					F20.0, F21.8, F29.6, F30.9, F31.1, F32.01, F40.8, F42.8 F43.25, F84.9, F89, F91.9, F92.8, F98.5				F06.68, F06.78, F06.82, F06.36, F07.8			

The *examination procedure* was described in detail earlier [9]. For assessing the psychomotor coordination in adolescents, a computerized device for psychomotor diagnostics (INTOX LLC, St. Petersburg, Russia) was used. The session included two tests. During the first test, visual–motor coordination was assessed when the subject made cyclic (left–right) hand movements in a limited frame with the maximum possible speed and accuracy. During the second test the sensorimotor reaction to visual and acoustic signals was assessed. The following parameters were evaluated: duration of the movement cycle (MCD, in ms) was measured as the mean time of lever movement from one marker to another and back; time to change the motor stereotype (TCMS, in ms) was measured as the time to achieve the required accuracy of movement in the new amplitude mode; the error of sensory correction of flexors (EFC, in %) and extensors (EEC, in %) was determined as the ratio of the mean deviation from the specified movement range boundaries to the total amplitude of lever movement for the entire cycle; smoothness of movement (SM, in%) is the contribution of the main harmonic in the Fourier spectrum of the movement; motor asymmetry (MA, in%) and the time for a simple sensorimotor reaction to visual and acoustic stimuli (TRV and TRA, in ms) were measured as the time from stimulus to the beginning of lever movement from the initial point.

Statistical analysis. In most cases, the distribution of experimental data did not correspond to normal law. Therefore, we used the nonparametric Kruskal–Wallis test followed by post-hoc Dunn's multiple comparisons test for unequal samples and Wilcoxon signed-rank test (Statistica 7 and GraphPad Prism 6). The results are presented as the median and interquartile range.

3. Results and Discussion

Comparison of the test results for the right and left hands in each group revealed differences only for the TCMS: T = 847.5, z = 2.31, $p = 0.02$ in the TD group, T = 622, z = 2.48, $p = 0.01$ in the MD group. To simplify the analysis, the values of other parameters were averaged for both hands.

In the group of T adolescents, the correlation analysis revealed associations of some parameters of motor reactions with age: MCD decreased (r = −0.54), i.e., the speed of movement increased, and the TRA decreased (r = −0.27); however, EFC and EEC correction increased (r = 0.27 and r = 0.43, respectively). No correlations between the motor response parameters and gender were revealed in this group. In the MD group, the correlation with age was statistically significant only for MA (r = −0.31). Females in this group demonstrated longer MCD (r = 0.27) and SM (r = 0.42).

We compared the parameters of psychomotor activity in the chosen age subgroups (see Table 1). In TD adolescents of the older subgroup, MCD decreased, while EEC increased in comparison with the younger ones (Figure 1). In both groups, a tendency to a decrease in MA in older adolescents was observed. For both the younger and older adolescents, the intergroup differences were found for MCD, TCMR, SM, EFC, and EEC. Adolescents from the group MD demonstrated higher speed, but lower accuracy of motor reactions in the test for psychomotor coordination. In the MD group, some parameters of simple sensorimotor reactions were higher than in the TD group: for TRV, this difference was statistically significant in the older subgroup and was present at the trend level in the younger subgroup; for TRA, a tendency to increase was revealed only in the older MD subgroup.

Analysis of the parameters of psychomotor coordination (MCD, TCMS, EFC, EEC) in groups TD, O and WO revealed only differences between TD adolescents and both groups of students with mental disorders. For all indicators, H (2, N = 133) > 21.0, $p < 0.001$ (Kruskal–Wallis test), and for intergroup differences, $p < 0.01$ (Dunn's test). No differences were found between the groups O and WO. On the contrary, analysis of parameters of simple sensorimotor reactions showed that TRV (H (2, N = 133) =13.691, $p = 0.001$) and TRA (H (2, N = 132) = 23.297, $p < 0.0001$) in group WO was longer than in groups TD and O ($p < 0.01$). Groups TD and O did not differ from each other in these parameters.

In TD adolescents, in contrast to adolescents with mental problems, parameters of psychomotor activity characterizing the speed and accuracy of movement correlated with age, but not with gender. According to the test 1 paradigm, cyclic movements were performed under visual control, i.e., we evaluated visual–motor coordination during performance of a simple motor task. Visual signals travelling with the dorsal stream to the parietal cortex [13] are necessary for planning and implementing the targeted action, as well as for processing the information about movement. Programming of the movement and feedback through the kinesthetic and visual channels are necessary for successful everyday activities. Different components of fine motor activity in TD schoolchildren develop at different rates, which is clearly seen from the profiles of maturation of visual–motor coordination during the ontogeny that were determined by some widely used tests [14]. Some psychomotor functions continue to mature in late adolescence and even in early adulthood. In our study, after the adolescents were divided into two age subgroups, the only parameter that differed significantly in these subgroups was MCD, which is interpreted in the research paradigm as an indicator of functional mobility of nervous processes [12]. TD adolescents of the older age subgroup performed cyclic movements at a higher speed. Though the accuracy of movement decreased, the differences did not reach statistical significance. For MD adolescents, this regulation was observed in both age groups: the speed of movement was higher, and error correction in accurately placing the cursor on the light mark was worse than in the corresponding control subgroups.

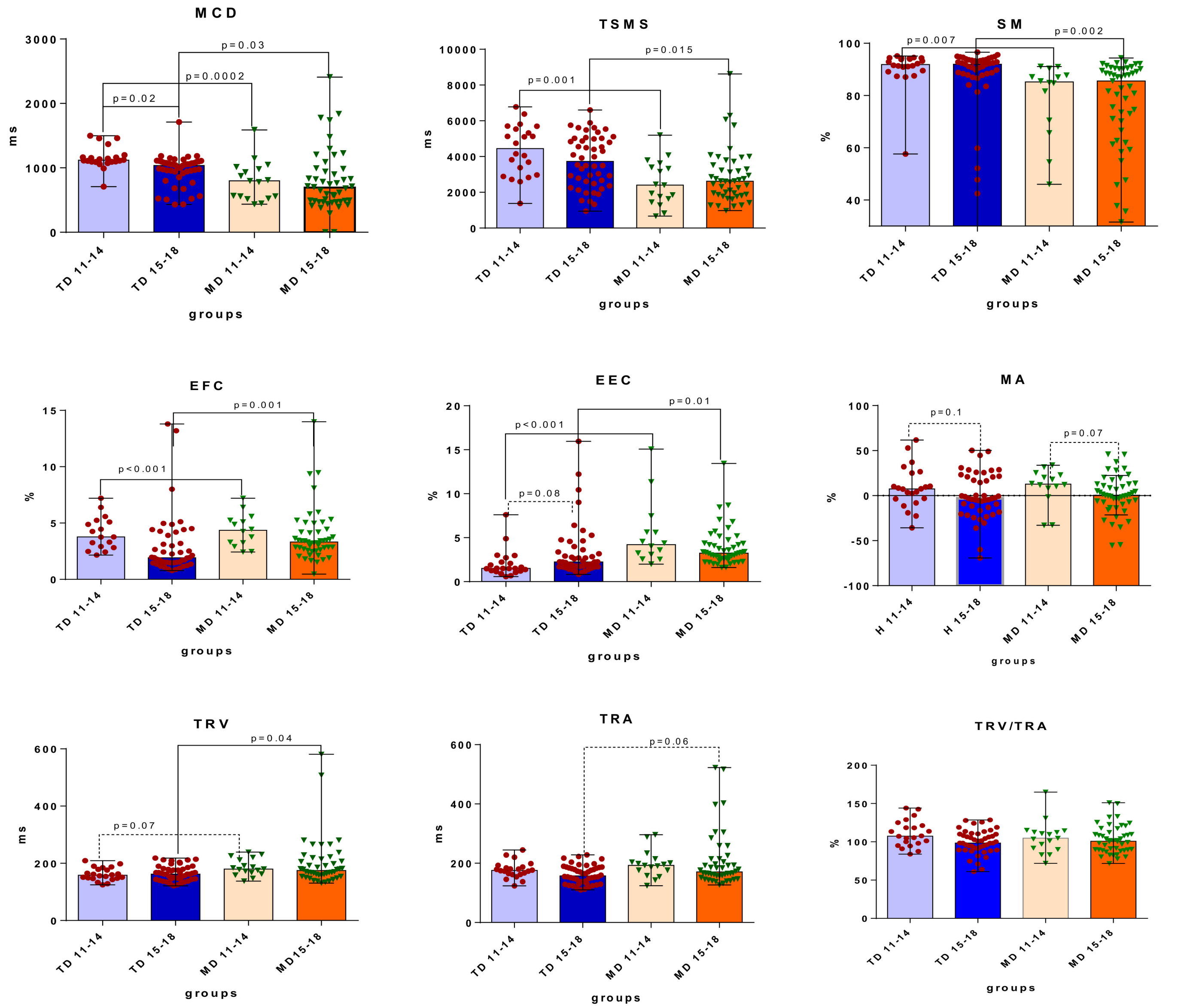

Figure 1. Parameters of psychomotor coordination and simple sensorimotor reaction in the younger (11–14 years) and elder (15–18 years) age subgroups of typically developing adolescents (TD) and adolescents with mental disorders (MD). Kruskal–Wallis test: MCD–H (3, N = 133) = 30.809, p = 0.0000; TCMS–H (3, N = 133) = 23,659, p = 0.0000; SM-H (3, N = 133) = 32.628, p = 0.0000; TRA-H (3, N = 132) = 13.569, p = 0.004; TRV-H (3, N = 133) = 11.707, p = 0.008; EFC-H (3, N = 133) = 34.789, p = 0.0000; EEC-H (3, N = 133) =33.172, p = 0.0000; MA-H (3, N = 130) = 8.314, p = 0.04. Results of post-hoc analysis are shown in Figure 1.

Cyclic movements in test 1 consisted of two phases: ballistic, mediated by excitation in the nervous system, and correcting, which provides accurate adjustment of the movement to the target mediated by the inhibitory processes. The correction is based on information received through the visual and proprioception feedback. The time and intensity of inhibition of the motor reaction are determined, first of all, by anticipation of the future result of the action. The neural mechanisms underlying movement planning and control have now been extensively studied [15].

In addition to the EEC/EFC, parameter SM reflects the balance of the processes of excitation and inhibition; the lower the SM, the greater the imbalance between the excitation and inhibition. In MD adolescents, SM is reduced in comparison with the control. Impaired coordination (including visual–motor coordination) is one of the most common motor dysfunctions in individuals with neuropsychiatric problems, including autism spectrum disorders [16], schizophrenia [17], bipolar disorder, borderline personality disorder [18], and depressive disorder [19]. In our study, subgroups O and WO did not differ by the parameters of visual–motor coordination of movements. Taking into account heterogeneity of the MD group, it can be hypothesized that the observed disorders of psychomotor coordination are unspecific and can be associated with a wide range of neuropsychiatric disorders. Visual–motor dysfunction can be related to impaired functioning of neural networks of attention, executive control, sensory and motor zones of the cortex and/or impairment of their interaction.

Time of sensorimotor reactions depends on the experimental conditions. In particular, movement limits, i.e., the need to stop movement at a certain point, increases the latency of the response. In our study, we tested only the speed of motor reaction, which, in fact, reflects the speed of pulse conduction in CNS. It has been previously demonstrated that preparation to and initiation of the movement are independent, each act has a distinct neural basis [20]. Detailed analysis of the components explains why the reaction time is usually slower than possible; movement initiation is delayed relative to the mean time needed for preparation to avoid the risk of movement initiation before it is properly prepared. In the MD group, LRV was higher than in the control group. These findings are consistent with the data of other authors who reported an increase in the time of a simple sensorimotor response in adolescents with mental disorders, unhealthy psychological symptoms, and emotional problems [21]. Adolescents from subgroup WO showed greater LRV and LRA in comparison with subgroup O and group TD. It is likely that residual organic brain disorders in adolescents in remission do not significantly affect the time for a simple motor reaction. The time for simple sensorimotor reactions in subjects with organic brain injuries (for example, after traumatic brain injury) during the recovery period did not differ from the control values [22].

4. Conclusions

Our findings indicate that students with mental health problems in both early and late adolescence showed significant differences from typically developing peers in almost all assessed indicators of psychomotor coordination and sensorimotor reactivity. The disorders of psychomotor coordination are unspecific and can be associated with a wide range of neuropsychiatric disorders. We suggest using simple motor tests as an affordable and cheap method for monitoring of the functional state of schoolchildren with neuropsychiatric problems.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Research Institute of General Pathology and Pathophysiology (Protocol No. 1, 22 January 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study and their parents (or legal representatives).

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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