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Original Research Article

Changes of electrophysiological parameters and neuropsychological characteristics in children with psychic development disorders after transcranial direct current stimulation (tDCS)

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ABSTRACT

Introduction: Recently, school maladjustment that is associated with the cognitive decline in children with minor central nervous system disorders has become one of the topical issues.
Aim: The aim of this research was a retrospective analysis of changes concerning neurophysiological and neuropsychological parameters in children with psychic development disorders after treatment employing the transcranial direct current stimulation (tDCS) technique.
Materials and methods: Study data of 128 children with learning disorders and 48 children with mild mental retardation, aged 8–12 years old, who had undergone a course of tDCS, were analyzed. The data of neuropsychological testing and electroencephalography (EEG) of 22 healthy children and 42 children with psychic development disorders who had undergone conventional treatment, aged 8–12 years old, were used as a control. For tDCS procedures 60–120 μA direct current was used, the stimulating electrodes area ranged from 2.5 cm^2 to 6.25 cm^2. Treatment session duration (ranging from 25 min to 45 min), as well as stimulating electrodes localization onto the scalp and the time of the procedure, depended on clinical goals, age, and the severity of disorders. The entire treatment course duration lasted 4–5 weeks: 5–9 procedures with 2–3 day intervals.
Results: A neuropsychological study revealed statistically significant improvement of higher mental functions in patients undergoing tDCS compared to control groups. Verbal functions improvement was observed in 80.0% of children with such disorders. In patients with dysgraphia, after tDCS the rate of mistakes in writing reduced 3-fold, the process of writing quickened. The ability to fulfill tasks requiring visual spatial analysis and synthesis also considerably improved. After the course of tDCS no cases of negative changes of EEG parameters were noted. On the contrary, the improvement of EEG parameters, showing their approaching the age norms, was observed.
Discussion: The study results indicate that tDCS enables one to not only change directionally the functional status of brain areas lying under electrodes, but also to influence actively the

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functional status of deep regulatory brain systems through the changing of modulatory cortical areas status.

Conclusions: Having practically no adverse effects, tDCS appears to be an effective correction technique with respect to higher psychic disorders for children with psychic development disorders.

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1. Introduction

In recent decades, school maladjustment that is associated with the cognitive decline in children with mild central nervous system (CNS) disorders as compared with the age norms has become one of the topical issues.[9] It is caused not only by the increase in the number of patients with this pathology, but also by the lack of effective techniques of medical rehabilitation.

This necessitates the development and practical application of new techniques that would enable one to realize the high potential of a child's brain flexibility. Transcranial direct current stimulation (tDCS), which has been widely used in recent decades in neurophysiological studies for a direct changing of CNS structures excitability, is one of such techniques.[15,17] In Russia, this technique is termed "transcranial micropolarization."[11] The fundamental physiological bases for this technique, including safety and general principles for the clinical use issues, were developed in the 1970–1980s and presented in the publications of the Research Institute of Experimental Medicine of the Russian Academy of Medical Science (RIEM RAMS).[16] On the basis of these data, we have employed this technique in clinical practice since 1988. Nowadays, tDCS is our routine technique used in various neurological and psychoneurological cases.[2,10,11]

2. Aim

The aim of this research is a retrospective analysis of neurophysiological (electroencephalographical – EEG) data and neuropsychological changes in the course of treatment sessions of tDCS at different positions of stimulating electrodes onto the scalp.

3. Materials and methods

During the period of 1995–2009 at the Municipal Rehabilitation Center for Children with Psychoneurological Disorders more than 1300 patients, aged 9 months to 17 years old, underwent tDCS treatment. The results concerning 176 patients, who underwent tDCS, aged 8–12 years old, were selected for this analysis: 128 children (77 boys and 51 girls) with learning disorders (F81.3 by ICD-10) and 48 children (26 girls and 22 boys) with mild mental retardation (F70 by ICD-10). Neuropsychological testing results and the EEG data of 22 healthy children (13 boys and 9 girls), aged 8–11 years old, and randomly selected results of 42 patients (24 boys and 18 girls), aged 8–12 years old, with psychic development disorders who had undergone the conventional treatment (drug therapy, sessions with psychologists, logopedists, and ergotherapists) served as a control.

Patients with psychic development disorders were divided into 2 groups (Exp. 1 and Exp. 2) according to the Markovskaya classification.[8] Group Exp. 1 (60 patients) included children with predominating signs of brain structures morphofunctional immaturity with no evident clinical signs of neurological abnormalities. Group Exp. 2 (68 patients) included children with symptoms of organic disorders of cerebral structures that are exhibited as concomitant neurological disorders (soft neurological signs, general and oral dyspraxia, mild pyramidal and extrapyramidal insufficiency, etc.). The third experimental group – Exp. 3 (48 patients) included children with mental retardation. Children from the control group with psychic development disorders were also divided into subgroups: Cont. 1 (19 patients), Cont. 2 (13 patients), and Cont. 3 (10 patients), respectively.

Children in groups Exp. 1, Exp. 2, and Exp. 3 along with conventional treatment similar to that provided in control groups (except for drug therapy) underwent sessions of tDCS according to the techniques described in the literature.[11] A 60–120 μA direct current was used, which enabled (taking into account the electrodes areas of 2.50–6.25 cm^2) one not to exceed the current density that is permissible for standard electrotherapeutical procedures of brain galvanization.[18] The equipment for medical electrophoresis Elfor-Prof (Nevoton, Russia) was used. The polarization session duration depended on clinical goals, age, and disorder severity level and ranged from 25 min to 45 min. A general course duration lasted 4–5 weeks: 5–9 procedures with 2–3 day intervals.

Three main electrode positions were used. The 1st position (a bipolar variant of tDCS, anode and cathode similar in size – 6.25 cm^2): the anode was positioned on the projection of the frontal cortex pole at the area Fp2 according to the international 10–20 system for EEG,[1] and the cathode was positioned on the ipsilateral mastoid region. The electrodes localization onto the subdominant hemisphere (for speech) in a bipolar position was used for all patients (the first 2 sessions). To define the dominant speech function lateralization, the dichotic listening was preliminary conducted.[3] A mild inhibitory influence on the subdominant hemisphere (tDCS during 35–40 min) enabled an activation reciprocally of the dominant hemisphere (for speech) by reducing the predominant hemisphere tonic inhibitory influence.[14] From the 3rd session in groups Exp. 2 and Exp. 3 the 2nd bipolar localization was used: the anode on the frontal region media-lateral surface, the cathode on the ipsilateral mastoid region. This localization was used for the alternate stimulation of subdominant (firstly) and dominant hemisphere structures (18–20 min for each hemisphere). This was dictated by the presence of paroxysms' signs in patients' baseline EEG parameters. Such a localization of the electrodes enabled an activation of the brain antiepileptic system structures, primarily the amygdale.[16]

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