

Diagnostic Tools for Children with Severe Multiple Developmental Disorders: Eye-tracking and Electroencephalogram Approaches

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Диагностические инструменты для обследования детей с тяжелыми множественными нарушениями развития: айтрекер и электроэнцефалограмма

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Abstract. Two pilot studies of children with profound damages of central nervous system were conducted by using eye-tracking. Design of electroencephalographic event related potentials (ERP) study is proposed. We aimed to test different approaches for diagnostic of this clinical group using eye-tracking and electroencephalography.

First study was an attempt to adopt classical diagnostic tool with verbal instruction to presentation on tablet with integrated eye-tracker. The result of this study reveals that it is impossible to use standard tools for very impaired children. Furthermore, we proposed several factors that could be crucial for eye-tracking tasks performance.

In the second study we tried to avoid tasks that require verbal instruction and voluntary control. Visual search task and Posner cuing task were presented trough tablet with integrated eye-tracker. No reliable records of gaze were obtained in this study.

Planning study is developed for using of ERP for diagnostic. We proposed that ERP passive oddball paradigm may allow us to examine psychological state and cognitive process

of children. In the end we discussed the conditions and requirements for both approach application in diagnostic children with severe multiple developmental disorders.

Keywords: *developmental disorders; psychological diagnostic; cerebral palsy; eye-tracking; electroencephalography (EEG); event related potentials (ERP); oddball task*

Аннотация. В статье представлены результаты двух пилотных исследований детей с тяжелым поражением центральной нервной системы, проведенных с использованием айтрекинга. Спроектирован дизайн исследования с применением электроэнцефалографических потенциалов, связанных с событием (ПСС). Целью работы стало тестирование различных подходов к обследованию данной группы лиц с использованием айтрекинга и электроэнцефалографии.

В первом исследовании сделана попытка использовать классический диагностический инструментарий, предъявленный на планшете со встроенным айтрекером и вербальными инструкциями. Результат этого исследования показал, что использование стандартных инструментов для данной категории детей крайне неэффективно. Кроме того, был выявлен ряд факторов, которые могут иметь решающее значение при выполнении заданий, предполагающих отслеживание взгляда.

Во втором исследовании была сделана попытка избежать заданий, требующих вербальных инструкций и произвольного контроля. Задача визуального поиска и задача с периферической подсказкой Познера были предъявлены через планшет со встроенным айтрекером. В этом исследовании также не было получено надежных записей взгляда.

Спроектированное исследование предполагает использование ПСС. Мы выдвинули гипотезу, что применение oddball-парадигмы позволит изучить психологическое состояние и когнитивные процессы данной группы детей. В заключении статьи обсуждаются условия и требования, необходимые для проведения обследования детей с тяжелыми множественными нарушениями развития.

Ключевые слова: *нарушения развития; психологическая диагностика; детский церебральный паралич; электроэнцефалография (ЭЭГ); потенциалы, связанные с событиями (ПСС); oddball-парадигма*

Introduction

The term *severe multiple developmental disorders* (SMDD) has traditionally been used in Soviet and Russian national special pedagogy to “designate a combination of three, or more pronounced developmental disorders” (Filatova & Karakulova, 2017, p. 7). A. M. Tsarev notes that mental retardation (Tsarev & Golovchits, 2014), which mainly manifests itself in a moderate, severe, or intensive degree, is the main one in the clinical picture of SMDD.

Since the adoption of the Law on Education in the Russian Federation (with amendments and supplements introduced by the law dated 2012), this category of children has

been recognized as *educable*. However, there are still difficulties in determining what and how to teach such people, which to some extent, is due to insufficient understanding of their abilities and capabilities (Federal Law No. 273-ФЗ, 2012).

Severe intellectual and psychophysical underdevelopment among SMDD people can be combined with local or systemic visual, hearing, musculoskeletal disorders, disorders of the emotional-volitional sphere, autistic disorders. Experts working with such children also detect current mental and somatic diseases (Order of the Ministry of Education... 2014). Children's speech is represented by inarticulate sounds or a set of several onomatopoeic or sound-imitating words. In cases when other people address such children, they perceive, first of all, intonation.

The clinical and psychological structure of the defect in children with SMDD is caused by the phenomena of "irreversible underdevelopment of the brain as a whole with predominantly immaturity of its cortex, primarily of the frontal and parietal lobes" (Lebedinskaya & Lebedinsky, 2011, p. 40).

This group of children is extremely heterogeneous. Their distinctive feature is the varying severity of intellectual impairment and psychophysical development among children of the same age. The level of formation of a particular mental function, practical skills can vary significantly.

Due to the specific features, children with SMDD are usually perceived as deeply mentally retarded, and professional literature seldom differentiates this category of children, taking into account the nature and degree of their intellectual impairment.

Specific features of SMDD children with moderate mental retardation (Shipicyna, 2002), as a rule, begin to appear in the first months of a child's life and subsequently lead to inexpressiveness, "diffuseness" of the main periods of developmental and age crises. It is difficult to define the shifts in the leading type of such children's activities and qualitative changes in their psyche and personality.

Such children demonstrate a slow and uneven pace of development. First of all, this applies to the late formation of motor functions. The children begin to roll over, sit down, get up, and occupy an upright position later than their equals in age. Fine motor skills remain undeveloped. It is difficult for such children to formulate a standard program of action. This problem affects their emotional shiftability and dynamics.

Depending on the predominance of the processes of inhibition or arousal, the behavior of the children can be different. Some children are very lethargic, passive, inhibited, while others, on the contrary, are very mobile, restless, animated. They continuously strive to do something, take various objects, try to manipulate them, but quickly drop what they have begun to do and start doing something else. Left to themselves, many children are practically not capable of any purposeful and creative activity.

Their storage of knowledge and ideas about the external world is small and often limited to the knowledge about the objects of everyday life. Their attention is extremely unstable; the process of memorization is mechanical; hand-eye coordination is grossly impaired; it is difficult for them to understand the situation, to single out the main as-

pect in it; to establish causal relationships; to transfer an already familiar, known action to new conditions.

Proceeding from the level of speech formation, S. D. Zabramnaya and T. N. Isaeva (2012) distinguish three groups of children. They are as follows: the group of children who have no speech, i. e., “speechless” or “non-speaking” children; the group of children with statements at the level of individual words and the group with the continuum of a phrase. All children have a limited perception of conversational speech and its situational understanding. Sometimes the first words appear in 3–4 years, a simple phrase only in 5–6 years. However, having appeared, the phrase remains slurred, speech-defected, rare, with multiple grammar mistakes. In their passive dictionary, there are words with clearly fixed meanings of objects from their immediate surroundings. There are the replacements of object names with the words denoting actions. Speech does not serve as a means of communication for such children. This state of speech, to a greater or lesser extent, persists throughout their life, which indicates the persistence of speech disorders.

The formation of the game for these children largely depends on the participation of the surrounding adults. Own play is usually limited to unfocused manipulations with toys. Only after repeated repetitions of an adult, joint reproduction of simple plots — such a child can repeat them individually.

When choosing toys, children give preference to well-known toys which are frequently a part of their everyday life. Most often, they repeat the same actions with toys in a learned manner. Some children have a chain of subject-game actions of 2–3 operations, but, as a rule, a complete plot does not arise. Self-introduction of game actions does not occur; the use of substitute toys is absent.

The degree to which hygiene skills and self-care are developed may vary. The greatest difficulty for children with moderate mental retardation is lacing, tying shoelaces, and button fastening, as well as skills associated with tools (brushing, combing).

The children may have a reduced need for contacts. The skills to interact with peers are hardly formed. In the process of interacting with adults, they are capable of accepting explanatory and educational assistance. Transfer of learned methods of action is possible only with the help of an adult. Own activities are possible, depending on the previously learned methods of action and organized assistance. During activity performance, the children can compare their actions with a sample. They have an emotional reaction to success and failure, an understanding of praise and criticism.

SMDD children with severe mental retardation (Shipicyna, 2002) do not initiate contact on their own even at the beginning of school-going age. They are characterized by passive submission. They experience difficulties in understanding oral address; they need a clear instruction with a gesture or a facial expression. Such children have little interest in new items. It is possible to draw their attention to something only for a very short time.

Children are not capable of transferring the shown mode of action to a similar task. They do not distinguish the functional purpose of many objects. The main way to learn

new things is only through joint action with an adult. Independent actions are only possible at the level of individual operations.

There is no self-control skill, children may be indifferent to criticism.

These children are only familiar with objects of their immediate environment (rooms, streets where they walk). They can show only basic parts of the body. The own speech of such children most often ranges from its complete absence to sound complexes and sound imitating.

Self-service skills are almost entirely absent, and they need care. Only a small part of the children tries to dress and undress on their own, but they do it ineptly, they confuse the sequence of operations. The skills of eating are better formed than other skills, i. e., they hold a spoon in their fist, although their eating is sloppy.

The co-existing disabilities of the *intense mental retardation* disorders in children with SMDD include the conditions which are as follows: cerebral palsy, epilepsy, hydrocephalus, microcephaly, malformations of internal organs. Therefore, one of the most pressing questions arising in relation to these children is the question of clarifying their intellectual state and learning opportunities.

Given these features, the examination of children with SMDD requires the use of special diagnostic techniques, since the classic diagnostic tools existing in practice make it possible to record the result of a specific child's performance or non-fulfillment of the proposed tasks, based on the level of formation of connections between the perception of the instruction, action, and speech. However, SMDD children do not use words to fulfill the function of building the relationship between sensorimotor processes and thinking.

Thus, the use of traditional methods often indicates the impossibility to objectively assess the level of development of higher mental functions, the level of learning and training, and other indicators.

Due to the difficulties of examining children who cannot express their reactions to tasks in the usual way — speech (sounds) or actions — it is necessary to organize the diagnosis using methods that are available to them using safe analyzers, primarily visual.

At present, there is a large body of world literature describing the use of eye-tracker technology in working with people with severe motor impairments, i. e., tetraparesis (Anand, Geethamsi, Pasha, & Kodali, 2013; Clarke, Loganathan, & Swettenham, 2012; Hernández, Encinas, Gómez, Rodríguez-Elías, & Gerardo, 2016; Lee et al., 2019; Myrden, Schudlo, Weyand, Zeyl, & Chau, 2014; and others), neurodegenerative conditions (Buena, Sato, & Hornberger, 2019), amyotrophic lateral sclerosis (Linse et al., 2017). These are pilot studies that are conducted on small samples of patients with disabilities — from 1 (Anand et al., 2013) to 11 (Linse et al., 2017). These studies aim to search for opportunities for forming alternative communication methods, or at least communicate the patients' needs to guardians (Hernández et al., 2016; Lee et al., 2019; Linse et al., 2017; Myrden et al., 2014). Only a small part of the research targets evaluating cognitive functions (Buena et al., 2019).

Currently, a large number of methods have been created that allow the examination of SMDD children (Baryaeva, 2003; Baryaeva, Gavrilushkina, Zarin, & Sokolova, 2012; Baryaeva et al., 2010; Boryakova, 2000; Levchenko & Zabramnaya, 2003; Morozov, 2015; Morozova, 2007; Nefedova, 2010; Shipicyna, 2002; Shipicyna, 2012; Strebeleva, 1998; Strebeleva, Mishina, Razenkova, Orlova, & Shmatko, 2004; Strebeleva, Venger, & Ekzhanova, 2002; Strebeleva & Zakrepina, 2018; Vereshchaga, Moiseeva, & Pajkova, 2017; Zabramnaya, 1988, 1998, 2005; Zabramnaya & Borovik, 2003; Zarin, 2015; and others), however, their use requires systematization, and may not be used for all children in this group. So, for example, the work by L. M. Shipitsyna (2002) describes the features of the diagnosis of sensory-perceptual functions and social development of children and adolescents with moderate, severe, and deep mental retardation, as well as social skills of young people with these features. In addition, it describes the specifics of parents' assessment of the formation of social skills and emotional and behavioral reactions in adult children with moderate and severe mental retardation. The work by S. D. Zabramnaya and T. N. Isaeva (2012) describes in detail the procedure for examining children in their first two weeks of schooling. In the recommendations by I. V. Vereshchaga et al. (2017), it is proposed to use a diagnostic kit, including the assessment of auditory, visual, tactile perception, and also, the conditions for the diagnosis, including the organization of positioning during the examination. S. S. Morozova (2007) points out how to diagnose children with severe complicated forms of autism through observation. In the appendix to this work, there are an extensive stimulus material and samples of diagnostic charts. The federal resource center for SMDD children in the city of Pskov (Russia) does an enormous work to create special tools for such children.

Nevertheless, the analyzed work practically does not provide any instrument operating examination methods. However, in recent years, it is proposed to use these methods for examining SMDD children: event related potentials (ERP) survey, electroencephalography (EEG), electrooculography (EOG), myography, eye-tracker (Antropova, Tretyakova, & Shulakov, 2018).

Research

Our **general aim** was to develop the diagnostic tool adopted with using of electroencephalography and eye-tracking for group of SMDD children. The diagnostic tool should allow to examine cognitive abilities of such children and help to develop their educational trajectory.

Experiment 1

The aim of the first study was to attempt to make an eye-tracing adaptation of classical diagnostic tools used in Psychological Medical Pedagogical Commission (PMPC) assessment (Anand et al., 2013) for observation SMDD children.

The participants were 10 foster-children of Yekaterinburg orphanage for disabled children, 5 of them are living in palliative department, other 5 are living in the department

of social rehabilitation. Participant's age was from 6 years 2 month to 13 years 3 months. Clinical diagnosis of participants are shown in the *Table 1*.

Table 1

Neurological status of participants

Participant	Age	Neurological status
Child 1 Boy	8 years 10 months	Residential period of severe traumatic brain injury. Post-traumatic hydrocephalus. Intracranial bypass surgery. Spastic tetraparesis, more on the left. Pseudobulbar syndrome. Structural focal epilepsy, remission.
Child 2 Boy	9 years	Structural focal epilepsy, remission. Secondary microcephaly. Pseudobulbar syndrome. Cerebral palsy, spastic syndrome.
Child 3 Girl	8 years 10 months	Organic damage to the Central nervous system. Internal hydrocephalus. Cerebral palsy, spastic syndrome. Pseudobulbar disorders. Structural focal epilepsy, remission.
Child 4 Girl	8 years 10 months	Occlusive tetraventricular hydrocephalus, decompensation. Cerebral atrophy of the 3rd degree. Condition after repeated intracranial bypass surgery. Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Pseudobulbar disorders. Structural focal epilepsy, remission.
Child 5 Girl	13 years 3 months	Cerebral palsy, spastic syndrome. Violation of motor activity level 3–4. Pseudobulbar disorders. Structural focal epilepsy, remission.
Child 6 Boy	9 years 4 months	Residual cerebral-organic insufficiency.
Child 7 Boy	6 years 2 months	Down syndrome. Autonomic dysfunction syndrome.
Child 8 Girl	8 years 5 months	Organic damage to the Central nervous system. Secondary microcephaly. Fetal alcohol syndrome. Myotonic syndrome.
Child 9 Girl	12 years 8 months	Organic damage to the Central nervous system. Microcephaly. Fetal alcohol syndrome. Structural focal epilepsy, remission. Syndrome of pyramidal, extrapyramidal insufficiency operated congenital heart disease.
Child 10 Girl	8 years 3 months	Residual cerebral-organic insufficiency.

Records were performed by Tobii PCEye eye-tracker integrated with Lenovo Miix 510 tablet.

Stimuli were standard tasks (Baryaeva, 2003) used for assessment of preschool and early school children and adopted for presentation on the tablet: assessment of standard visual figures differed by color/shape/size; recognition of images, congruent to the observer's instruction: parts of the face, body and times of day, familiar things (spoon, ball), and familiar actions (ablutions, sleeping). All the stimuli were adopted for perception features of SMDD children under the following demands:

- Hand-drawn realistic pictures.
- Low detailed images, with simple shapes. Not simplified depiction of objects (e. g. a window was not depicted by one line; a star was not depicted by a simple shape etc.).
- An absence of optical and cognitive illusion, ambiguous or indistinct images.
- Illustrations with a tendency to planar painting.
- Avoiding cartoon-like and pseudo-childish depiction.
- Using of Luscher's color circle, avoiding of ambiguous shades and complex colors.
- Simple objects composition with definite, without overlapping, objects positions.

Stimuli were presented by software MS PowerPoint. The two-dot calibration was performed. Records were conducted in the playing room. Two children were laying on the couch, other one was staying in verticalizer, other three were sitting in wheelchairs, and others were sitting by themselves on a chair.

Gaze data were analyzed frame by frame for defining gaze direction. Only qualitative analyses of records were performed, as due low calibration quality and big amounts of artifacts quantitative analysis couldn't be performed.

Areas of Interesting (AOIs) were made for each object on the picture. Following measures were used for evaluation of task performance: fixation duration on AOIs before instruction; fixation duration on AOIs after instruction; differences in fixation durations on AOIs before and after instruction. The response to the instruction was evaluated as general difference in gaze movement before and after instruction presentation.

Records were carried out for 8 participants, and were not conducted for two participants: one of them refused to establish an eye contact and gone from the room, and another one's gaze could not be record due sever permanent nystagmus with great amplitude. General task performance description is provided in the *Table 2*.

It is important to notice that only 4 children were able to recognize standard visual figures. Five children were able to recognize parts of the face, body, and familiar actions. Only one participant was able to recognize time of a day.

The attempt of adaptation classical PMPC diagnostic tools in general was unsuccessful. The main reason of this was applying of standard tasks included verbal instruction. During the experiment the most of participants demonstrated poor response to the instruction or absence of such response that was revealed by the absence of difference in gaze behavior before and after instruction presentation. Such results could be interpreted by the several factors: general speech underdevelopment, low receptive language development, low executive functions development, visual or speech perception impairment, agnosia.

Furthermore, a small number of correct responses could be result of that educational materials and programs used for SMDD children did not include materials that related to task, used in the experiment.

Table 2

General task performance description

Participant	Calibration quality	Instruction response	Task performance
1	One point complete. Poor	Impossible to assess	—
2	No calibration	Impossible to assess	—
3	<i>Record did not conducted due nystagmus</i>		
4	Two points complete. Poor	Expressed poor	Differences in fixation duration before and after instruction for a few tasks.
5	Two points complete. Average	Expressed poor	Differences in fixation duration before and after instruction for a few tasks. Gaze shift after instruction presentation.
6	Two points complete. Average	Expressed enough	Differences in fixation duration before and after instruction for a few tasks. Gaze shift after instruction presentation. Motor responses.
7	<i>Record did not conducted due refuse of participant</i>		
8	Two points complete. Poor	Expressed poor	Differences in fixation duration before and after instruction for a few tasks.
9	Two points complete. Poor	Expressed poor	Differences in fixation duration before and after instruction for a few tasks. Motor responses.
10	Two points complete. High quality	Clearly expressed	Gaze shift after instruction presentation. Motor and verbal responses.

Additionally, we proposed following problems and possible way of solution that could help improve the quality of eye-tracking diagnostic:

(1) **Problem.** Assessed children mostly have different motor impairments in the range from local limbs paresis to severe spastic diplegia. Due the motor impairments the pose of child during assessment could not allow to locate enough good eye-tracker related to child.

Solution. Application of special verticalizer or couch with eye-tracker's support arm for achievement optimal interlocation of participant and eye-tracker

(2) **Problem.** The speciality of SMDD children is low level of sustained attention, high fatigability. Our experiment was conducted in the playing room with average luminosity and in presence of several experimenter and PMPC specialists. Such ambience could decrease the quality of recording.

Solution. It is crucial for SMDD children eye-tracker's experiment to minimize distracting effects: luminosity must be low (but not absence); exclude any noises; experiment must be carry out by one experimenter, it is acceptable presence of one caregiver; record's should be conducted when children are in tranquil but vigorous state.

(3) **Problem.** Some children from rehabilitation care demonstrated good level of cognitive development and were trying to take motor responses to the instruction questions, and therefor interrupt the record. On the other hand, other children with severe complex impairments demonstrated low calibration and record quality and they could not be assessed.

Solution. We need to specify characteristics of SMDD children who may be assessed by eye-tracking. Using tablet eye-tracking for less impaired children may have advantage only for special tasks (e. g. antisaccade task). Children with severe neurological and developmental diseases could have strong damage of essential for eye-tracking cognitive, motor, and communicative skills.

Results of the first experiment allow us to conclude that diagnostic procedure of SMDD children should exclude a verbal instruction. For this end we supposed to use tasks and procedures adopted for the infant studies.

Experiment 2

Aim of the second experiment was to test SMDD children with specially developed stimuli and procedure based on that used for infant researches and do not need any instruction.

The participants were 6 foster-children of Yekaterinburg orphanage for disabled children living in palliative department. Participant's age was from 4 to 11 years. Clinical diagnosis of participants are shown in the *Table 3*.

There were two kind of tasks used in this experiment.

The first task was classical visual search task adopted for infant research. Stimuli and procedure were similar to those used in study C. H. M. Cheung, R. Bedford, M. H. Johnson, T. Charman, and T. Gliga (2016).

There were total 16 images with circle array of 8 symbols. 7 symbols were distractors letters "X" and one symbol was a target. In 8 images target was "+" and in other 8 target was a capital letter "O". Duration of image presentation was 1.0 s. Target position was changed in each image in random sequence and never repeated. Before each image presentation the fixation cross in the center of screen was shown for a 1.0 s. The image presentation sequence was random.

The second task was modification for eye-tracking of M. I. Posner (1980) cueing task used for attention assessment.

We used following presentation sequence: fixation cross in the center of screen for a 1.0 s; left or right cue; fixation cross in the center of screen for a 1.0 s; left or right target. If the target and cue position was on one side the condition count as congruent, otherwise the condition was incongruent. There were total 10 trials with random side and condition presentation.

Table 3

Neurological status of participants

Test subject	Age	Neurological status	Related violations
Child 1 Girl	14 years	Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Pseudobulbar disorders. Structural focal epilepsy, remission.	Convergent strabismus, dysphagia, dysphonia, lack of articulation, tongue deviation.
Child 2 Boy	10 years	Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Pseudobulbar disorders. Structural focal epilepsy, remission.	Exotropia, dysphagia, lack of articulation, tongue deviation.
Child 3 Girl	5 years	Multi-level occlusion hydrocephalus, compensation stage. State after multiple operational interventions. Total encephalomalation. Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Pseudobulbar disorders. Structural focal epilepsy, remission. Generalized kinesigenic hyperkinesis.	Exotropia, dysphagia, dysphonia, lack of articulation, tongue deviation.
Child 4 Boy	11 years	Cerebral palsy, spastic syndrome. Violation of motor activity level 4. Pseudobulbar disorders. Structural focal epilepsy, remission.	Dysphagia, lack of articulation.
Child 5 Girl	4 years	Multi-level multicystic hydrocephalus, compensation stage. State after multiple bypass operations. "Disconnected" fourth ventricle syndrome. Total encephalomalation. Cerebral atrophy. <u>Epileptic encephalopathy (axial tonic spasms, clonic attacks)</u> , remission. Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Pseudobulbar syndrome. Palliative status.	Exotropia, horizontal nistagmus, dysphagia, dysphonia, lack of articulation, tongue deviation.
Child 6 Boy	9 years	Cerebral palsy, spastic syndrome. Violation of motor activity level 5. Structural focal epilepsy, remission. Palliative status.	Convergent strabismus, dysphagia, lack of articulation, tongue deviation.

Gaze data were analyzed frame by frame for defining gaze direction. In visual search task the fixation duration on target and relative fixation duration on target / distractor were measured. In Posner cueing task fixation duration on target and time from target appearance to gaze shift.

Records of gaze were taken only from 2 participants. Furthermore, calibration quality of these records was very low therefore analysis could not be performed.

However applied tasks did not demand any instruction or voluntary control of attention or movement, we were not being able to get any reliable results from our participants. Records we have got could not be used for defining of gaze direction, moreover four participants were not recorded because of their states. It should be noted that participants were very inactive: an absence of any vocalizations, poor oculomotor activity etc. Such behavior may related to severe neurological state or to applying of sedatives for participants.

Based on two attempts of SMDD assessment we may propose that applying of eye-tracking technology for such participants diagnostic or rehabilitation is almost impossible. Thus, we stated the next experiment aim is to test the reliability of using for SMDD children assessment of ERP in oddball paradigm.

Experiment 3

Aim of the third study is to test applying the ERP in oddball paradigm for assessment of cognitive functions in SMDD children.

We are planning to measured ERP in 15 foster-children of Yekaterinburg orphanage living in palliative department with severe multiple development disorders in the age range from 4 to 13 years.

We are going to use passive oddball paradigm. There are a lot of study demonstrated the possibility of using this paradigm for consciousness level evaluating (Erlbeck et al., 2016) or, at least, sensitivity of passive oddball for severe consciousness and cognitive impairments (Real et al., 2016). Whereas some locked-in state patients may not exhibit brain response to such stimulation (Lugo et al., 2016), there is no doubt that existing of the response will reveal the presence of basic cognitive processes.

We will use passive oddball paradigm with two tones: standard (440 + 880 + 1760 Hz) will presented 400 times; deviant (247 + 494 + 988 Hz) will presented 80 times. All the stimuli durations will 50 ms, with graduating volume increasing during 5 ms in the beginning and decreasing in the end. Stimulus onset asynchrony (SOA) will varied from 950 ms to 1050 ms. Stimuli will be presented binaurally by speakers placed on the 50 cm distance of both sides from participant. Sound intensity level will be 70 dB.

Records will be conducted in acoustically insulated room with low illuminance about 50–100 lux. ERP will be recorded by 19-channel system NVX36 (Medical Computer System, Russia). Electrodes will be placed according to 10–20 system. Additionally bipolar vertical and horizontal oculography components will be measured. Scalp electrode impedance will be less than 50 kOhm during all experiment. The mastoid reference will be used. The digitalization rate will 1000 Hz, and the low pass filter will 500 Hz.

For data processing we will use software package EEGLab and ERPLab for Matlab (MathWork, Inc.). Records will be filtered and clear from oculographic artefact. Epochs will be marked in the interval –200 ms to 700 ms relative to the stimulus presenting. Baseline correction will be performed in the interval –200 to 0 ms. The Pz, Cz, and Fz channels will be chosen for ERP measurement.

We suppose that some of SMDD children will demonstrate different amplitude of ERP components N2, P3a and P3b for standard and deviant stimuli in passive oddball task. Moreover, we guess that existent of such differences will be connected with better neurological and psychological state in children. The results are supposed to be used for developing if ERP based diagnostic tool for SMDD children.

Discussion

Eye-tracking technology is widely used in diagnostics and rehabilitation of adult patients with severe central nervous system impairments (Anand et al., 2013; Buena et al., 2019; Lee et al., 2019; Linse et al., 2017; Myrden et al., 2014). However, for adaptation the eye-tracking for SMDD children it is needed to develop special stimuli and procedures. The applying of eye-tracking for SMDD children with profound intellectual disability and living in palliative departments of special orphanages may demands additional participant selection. Thus, from eleven palliative participant there were only two reliable eye records.

Therefore, we may conclude that eye-tracking applying is preferable for children without severe impairments of visual pathway, primary visual areas; absence of II, II, IV, and VI cranial nervous nucleus and pathways damages. Apparently most of SMDD children from palliative department have got some of the structural-functional impairments that made eye-tracking diagnostic almost impossible.

A small amount of correct answer were given by participants who pass the eye-tracking in the first experiment could be explained by absence of corresponding tasks and materials in the educational program that was provided for participants. These results should be also considered by the specialists of PMPC.

The given results determine the necessary of develop new methodic materials for SMDD children that must be chosen individually depends on disease features and prognosis, factors influenced on the record quality. Furthermore, it must be developed the diagnostic tool that allow to control the influence of such factors and evaluate psychological development of children.

The reliability of applying the measurement of electroencephalographic ERP in passive oddball paradigm for children assessment based on great body of studies. Differences in brain activity could be observed even in newborn (Partanen, Pakarinen, Kujala, & Huotilainen, 2013) or in first year of life infants (Choudhury & Benasich, 2011; Friedrich, Weber, & Friederici, 2004). Moreover, ERP measurements could predict further psychological development (Choudhury & Benasich, 2011), allow discriminating alertness and sleeping states (Friedrich et al., 2004). Passive oddball paradigm successfully used

for assessment of patients in minimally conscious state and in vegetative state (Erlbec et al., 2016; Risetti et al., 2013) and for locked-in state patients (Lugo et al., 2016). From this perspective we suppose that applying of passive oddball paradigm for assessment of SMDD children with profound brain damages will allow us evaluate their psychical and cognitive state with more accuracy.

Conclusion

We suppose that using of eye-tracking for SMDD children is possible under definite criteria:

- (1) Development of exclusion and inclusion criteria (based on actual neurological state, anamnesis, speech and motor abilities, and developmental impairments).
- (2) Development of special research procedure.
- (3) Development of diagnostic tools for tablet integrated eye-tracker.

Moreover, for diagnostic of SMDD children with profound nervous system damages it looks useful the applying of measurement of ERP in, among other things, passive oddball paradigm.

We propose that using of these technologies may improve the range and sensitivity of standard diagnostic tools and give us additional information about psychical processes of SMDD children.

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