Experimental design for studying brain activity and behavior of a child in the process of solving elementary cognitive tasks

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***Abstract*—Modern education in the digital reality of the 21st century has great potential to use various strategies to personalize the learning process in order to improve the teaching system. Here, important tasks is an objective assessment of the psychophysiological state of the child in the learning process and the development of the pedagogical concept of using the data obtained to personalize the learning of elementary school students. The current study proposes the design of a neurophysiological experiment aimed at studying the cognitive and executive functions of primary school children. Tasks aimed at visual search, working memory and mental arithmetic are proposed as testing elementary cognitive functions.**

***Index Terms*—Neurophysiological experiment, brain activity, cognitive function testing, personalization of learning process**

I. Introduction

One of the most important and actual directions of research for scientists from all over the world is the study of the work and functioning of the brain, including the study of specificity of the children's brain. The amount of work related with testing the cognitive functions of children and the analysis of the data obtained has been increasing significantly over the past decade [1]. And this is not surprising - the results of these experiments can help both to improve teaching methods and to develop individual learning trajectories, and for personal rehabilitation of students with developmental disorders of the nervous system [2]–[6].

In particular, researches using neuroimaging techniques (for example, electroencephalography) are of particular importance because they make it possible to research changes in the way the brain works during the performance of tasks by the subject [7]–[17].

We are planning to conduct a neurophysiological experiment based on testing elementary cognitive functions in children using EEG. EEG being one of the most used and trusted method of neuroimaging was chosen as a tool to study brain activity. Specifically, that the EEG allows to carry out time-frequency analysis covering all basic rhythms of the brain, to restore sources of activity and to study functional networks forming in the brain. The aim of the experiment is studying of various aspects and features of brain activity during information assimilation, as well as the identification of neurophysiological factors that affect the process of learning new skills, in order to optimize the learning process. The tasks of the experiment are both studies of the child's brain activity and behavior registration during problem-solving involving elementary cognitive functions (memory, attention, sensory information perception speed) and analysis of the data obtained in order to determine the current state and general psychophysiological features of the child followed by creation of an interactive educational environment for individualization and improvement of the educational process efficiency. It is also worth noting that successful cognitive problem-solving require the development of "executive functions," which are high-level cognitive processes involving planning, arousal, switching, control, and inhibition [18]–[20].

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II. Experimental design

The target group of the experiment will be three groups of 30 pupils, as well as their parents and teachers: a first and second group with pupils aged 8-9 and 11-12 years respectively, and a control third group with pupils aged 13-15 years. The study of the first two groups will be conducted over a period of 3-5 years.

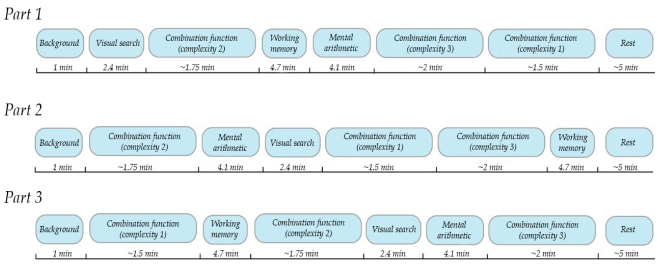

Fig. 1. General scheme of the experiment. Example distribution of blocks in each part

The experiment will consist of three parts (one part lasts ≈15 minutes), each consisting of 6 blocks: one block each on visual search, mental arithmetic and working memory, and three blocks on the ability to combine and use several elementary functions at once (fig.1).

The block with the working memory test based on Sternberg memory task with two-digit numbers [21]. After an instruction to the task, the examinee is presented with a white cross to attract attention, two lines of two-digit numbers, some of which are replaced by the symbol "*" (2, 3 or 4 numbers from 7 remain visible) and a black screen of 6.5 seconds, after which the examinee is presented with one number. He has to remember if this number was among those presented earlier. The sequence described is a single trial, in each block the subject will be given 24 trials, half of which are aimed at the target trial and the other half at the non-target trial. The trials are also divided into three identical parts with different levels of difficulty (see fig 2a).

The visual search test block is implemented by searching for a target two-digit number in a matrix of other numbers [22], [23]. After instruction to the task, the subject is presented with a white cross to attract attention, a two-digit number to memorize and a matrix of numbers from which to find the previously shown number. The sequence described is one trial, in each block the subject will be given 16 trials, eight trials per two type tables (see fig 2b).

The mental arithmetic test block is implemented through arithmetic with two-digit numbers from which single digits 1,2 or 3 are subtracted. After instructions for the task, a black screen, a white cross to attract attention, and a mathematical equation alternately appear in front of the test taker. The aim of the subject is to determine whether it is correct by selecting the correct option (yes or no) on the screen. The sequence described is one trial, in each block the subject will be given 24 trials, half of which are aimed at the target trial and the other

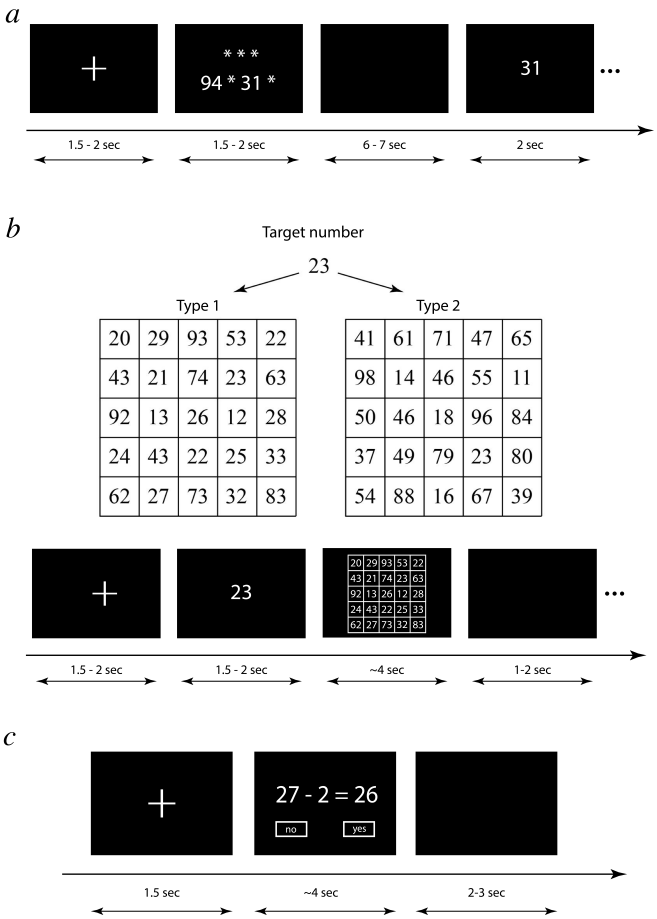

Fig. 2. Scheme of the different blocks: a) on working memory; b) on visual search; c) on mental arithmetic

The block with a test for the ability to combine and use several elementary functions simultaneously is implemented by searching for a sequence of numbers in a matrix. After instructions for the task, the test person is presented with a white cross to attract attention and a matrix of numbers in which one must first find the number given in the instructions, and then mark the number that is N less than the previous number. N is a pre-determined number (1, 2 or 3). The described sequence is one trial, in each block the test person will be given 1 trial, in each part there will be three blocks with different difficulty level (the difficulty level is equal to the number N given in the instruction)

The selected tests allow studying elementary cognitive functions separately and in aggregate. So, the Sternberg paradigm aims to explore the different characteristics of short-term memory [24]. The visual search paradigm (searching for a target two-digit number) is to measure attentional capture and oculomotor control to memory [25]. The arithmetic task allows studying the abstract representations in the brain [26].

Note, abstract representations are an important part of many aspects of learning, problem-solving, and understanding. For example, abstractions provide a relationship between perceptual experience and theoretical understanding, as in the case of constructing a standard unit of measurement. And finally, several elementary functions task allow studying Integrative functions in the brain.

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