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Technological Support of Estimating Functional Opportunities of Higher Parts of Central Nervous System in the Individuals with Auditory Deprivation

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ABSTRACT: *A new computerized technology of investigating and estimating the individual features of higher parts of the central nervous system in people with auditory deprivation is offered. The essence of the offered technology for investigating and estimating individual functional opportunities of higher parts of the nervous system of an individual with auditory deprivation consists in using the specific sequence of representing the load tests with corresponding criteria of estimating the processed information of different level of complexity, which are applied on hardware devices developed by us. We represented the scales for estimating the parameters of simple and complex sensorimotor reactions, speed qualitative and quantitative indicators of processing information based on the typological properties of the nervous system, such as the functional mobility, strength and balance of basic nervous processes. We suppose that the research using the same tests and criteria of estimating neuro-dynamic properties will increase the opportunity for the analysis of different experimental material and enhance its value.*

Keywords: *auditory deprivation, functional mobility, individual properties of higher parts of the central nervous system, information processing, sensorimotor reactions, steadiness of nerve processes,strength.*

I. INTRODUCTION

The method of studying the properties of the basic nervous processes, such as functional mobility (FMNP), strength (SNP) and steadiness of nervous processes (StNP), has been widely used in the neurophysiology of higher parts of the central nervous system, differential psychophysiology, labour physiology, space and sport physiology for the research of individual differences of a man according to the indicators of neurodynamic functions [1].

Modern solution of many applied and fundamental problems in biology and medicine combines engineering and biomedical knowledge, the tools, methods and research. The development, application and engineering support of methods, the technologies to diagnose and recover the lost organs, parts of organs and their functions in order to improve the life quality of people with physical disabilities and limitations, are of particular interest. Nowadays, comprehensive and integrated understanding of living organism functions, as well as the prediction of physiological reactions, is not possible without the use of engineering strategies and technologies including computer modeling for the analysis of experimental data [2, 3]. The revolution of computerization and automation of experiments brought a lot of new results in the study of higher parts of the central nervous system and expanded the opportunities of getting more qualitative and diverse material [4, 5, 6].

However, the questions about the study of higher nervous activity (HNA), especially of the central nervous system, the sensory abilities of the body are far from being solved [7, 8, 9], especially in conditions of function deprivation [10].

The problems, associated with the replacement or restoration of the lost mental, sensory and motor abilities, the introduction of robots controlled by nerve impulses, the development of microelectronic implants to correct and improve the functions of the central nervous system, the analyzer functions, require the serious study of the brain and nervous system of the people with the lost hearing functions, sight, movement, and speech.

Undoubtedly, the analysis of work principles of the brain with sensory deprivation allows to identify characteristic neural patterns, to evaluate the work of a number of brain structures, to diagnose and predict possible pathology [11]. Besides, the problems associated with the functional interaction of sensor systems, remain unstudied [12]. The given issue becomes more relevant due to the steady growth of people with auditory deprivation.

To investigate the brain mechanisms in neurophysiology, M.V. Makarenko's and V.S. Lyzogub's method of studying the features of basic nervous processes is widely used [13], as well as various methods of processing information according to the parameters of simple and complex reactions of choosing different signals [3, 14, 15].

We propose to use "Diagnost-1" and "Diagnost-2" computer systems, which make it possible to record, evaluate and analyze the individual characteristics of neurodynamic functions while presenting a series of tests with different complexity for processing information of auditory (at the deprivation of visual function) and visual (at the deprivation of auditory function) modality, as well as to determine functional state of auditory analyzer at various dysfunctions of hearing (hearing loss, otosclerosis, acoustic injury, etc.) [1, 16, 17].

The complexes can be used to diagnose, to conduct professional diagnostics, to select, to evaluate and monitor the professional qualities of the employees for whom the state of auditory and visual analyzers has a decisive role, as well as, in medicine, to study individual psycho-physiological characteristics of children, adolescents and adults with impaired sight or hearing, and without them.

The identification and evaluation of individual features and functionality of higher parts of the central nervous system in two versions "Diagnost" are carried out in three modes: "optimal rate", "the imposed rate" and "feedback". Processing of the information of different modality in the mode "optimal rate" allows to determine and evaluate the speed of auditory- and visual-motor reactions of different complexity level: for indicators of simple reaction (IVMR, IAMR), the reaction of choosing one (RC1-3) and two of three stimuli (RC2-3), as well as to determine sensor (SC), motor (MC) and central (CC) components of processing complex information.

FMNP, SNP and StNPare studied using two other modes. The peculiar feature of "feedback" mode consists in the fact that signal exposure changes automatically according to the character of answer while performing test task. The exposure decreases after the correct answer; it increases after the wrong one in the range of 900-20 ms.

"Diagnost-1" complex uses words, geometric figures, colours, their various combinations as stimuli. There is an automatic change of signals and registration of results.

"Diagnost-1M (2)" complex works with clean tones, which are described by right sinusoid, and has a wide range of auditory stimuli: clean and noisy tones, different phonemes and words with different semantic load.

The basic requirements for computer systems are the minimum processor clock speed of 100 MHz, the minimum size of RAM – 640 KB, the minimum requirements for the monitor of VGA type with the resolution of 640 x 480, 16 colours. We were able to form the valid scales in order to determine psycho-physiological functions at a healthy contingent of people aged 6-80 in processing stimuli of visual and auditory modality. Nowadays, we continue to collect data at the contingent of people with the deprivation of auditory function. The goal of the research is to demonstrate the opportunity to determine the level of processing visual information in the individuals with auditory deprivation.

II. METHODOLOGY

In this study, we focus on the method of identifying and estimating simple and complex sensorimotor reactions based on "Diagnost-1" complex for the analysis of the opportunities of higher parts of the central nervous system to ensure maximum possible for each individual level of performance with the unmistakable differentiation of positive and inhibitory stimuli considering the speed, quality and quantity of their processing that are stipulated by both highly genetically determined typological properties of HNA and the peculiarities of memory, thinking, reception and attention function [1, 17].

The investigation and evaluation of neurodynamic features using computer systems with our software is conducted on the basis of the quality results of information processing, which is carried out in three modes: "optimal rate", "imposed rate" and "feedback". In the "optimal rate" mode, i.e. the most comfortable for each individual, we studied the parameters of sensorimotor reactions of different complexity degree while presenting and processing mental load. The speed and qualitative and quantitative indicators of HNA features, FMNP and SNP, were diagnosed using two other modes. Subject (geometric shapes, colours) and verbal (names of plants, animals and inanimate objects) characters were used as mental load for processing information. In the "optimal rate" mode, we can get the value of latent period of simple visual-motor reaction (LP SVMR), the reaction of choosing one of three signals (LP RC1-3) and latent period of reaction of choosing two of three signals (LP RC2-3).

To determine LP SVMR, the investigated individual is offered an instruction: "You should press and release the button with your right (left) hand as quick as possible when you see the signal in the form of colour, geometric figure or words on the screen". The device registers and shows on the screen the average value of latent period for 30-50 uses (by the decision of the experimenter) homogeneous stimuli and other statistic indicators of variation number (standard deviation, the average error, coefficient of variation) in a real scale. The obtained results are recorded in the protocol or duplicated on a paper by a printer. We used 30 signals with an exposure of 0.7 seconds.

To get LP RC1-3 value, the investigated individual is offered an instruction: "You should press and release the right button as quick as possible when you see the signal of red colour or the figure of square on the screen. Don't press the button for other signals". The device registers and shows the average values of LP RC1-3 on the screen with the similar list of the indicators of a variation number as with determining LP SVMR and indicating the number of false reactions (the total number and for each hand separately).

When determining the time of complex sensorimotor reaction of choosing two of three stimuli, the load of information processing is carried out with both hands. The investigated individual is offered an instruction: "You should press and release the button with your right hand as quick as possible when you see the signal of red colour or the figure of a square on the screen. You should press and release the button with your left hand when you see the signal of green colour, the figure of a circle or the words with the names of plants on the screen. Don't press the button with your right or left hand for other signals (yellow colour, "triangular" figure and "inanimate object" words)". The device registers and shows the same list of statistic indicators as in the previous submodes, i.e. for the registration of LP RC1-3. When determining the latent period in the last two tests we presented also 30 signals with the exposure in 0.9 seconds.

The values of latent period, which were the least in three measurements, should be considered as the indicator of sensorimotor reactions of an individual. Such an approach of estimating the time of visual-motor reaction is stipulated by the analysis results of experimental data obtained in the same investigated individuals performing the same task for several times. This task was performed for 20 times in our special conducted experiments. The same investigated individuals performed it during 5 days, others – during a month. The test was not used more than 5 times in the day of investigation. The latent period was found to be stabilized and reach its optimal value mostly for the first three investigations. Therefore, we recommend to use three repetitions of the same test in order to find individual features of sensorimotor reactions, and the best results of these measurement – to estimate these features.

The information was processed using "Diagnost-1" computer complex in the "feedback" mode [1, 17]. The investigations were carried out in compliance with the bioethical norms and regulations of the Helsinki Declaration of 1975, after a voluntary written agreement of every investigated individual. Geometrical figures were used as visual load to differentiate information. We found a number of false reactions and total number of the processed visual stimuli for 5 minutes as quick as possible differentiation of positive (circles, squares) and brake (triangles) stimuli in the "feedback" mode. At the same time, the presentation of each of the next stimuluswas automatically changed depending on the correctness of the answer. After the presentation of the correct answer, the signal exposure was decreased, and in case of error - lengthened by 20 ms.

We considered speed, quality and quantity of information processing stipulated by both highly genetically determined typological peculiarities of HNA and the functions of memory, thinking, reception and attention. The results were processed with the methods of non-parameter statistics, with Excel-2010 service program.

III. THE OBTAINED RESULTS

To characterize the features of sensorimotor reactions, we offer the scale of their estimation, which can be specified. Visual-motor reactions on subject and verb stimuli have five grades according to this scale (Table 1). The distribution into five levels (for convenience) is made on the basis of the results of processing a large number of digital arrays in accordance with the average borders of latent period values. The values used for the construction of scales were registered in males aged 14-45; therefore, the state of sensorimotor reactions in this age can be estimated with these scales.

Table 1. Scales of estimating latent periods of sensorimotor reactions of different complexity in the individuals with normal auditory function and deprivation

Level of information processing	Latent period of visual-motor reaction (ms)					
	Healthy			Deaf		
	LP SVMR	LP RC_{1-3}	LP RC_{2-3}	LP SVMR	LP RC_{1-3}	LP RC_{2-3}
High	≤182	≤280	≤335	≤210	≤320	≤410
Upper-intermediate	183-226	281-323	336-390	240-211	350-321	430-411
Intermediate	227-292	324-398	391-463	265-241	380-351	450-431
Pre-Intermediate	393-330	399-433	464-501	290-266	410-381	470-451
Low	≥33I	≥434	≥502	≤291	≥411	≥471

The characteristics of maximum speed of processing information in differentiating positive and brake stimuli show the level of FMNP, and total number of presented and processed signals for the fixed time shows the indicator of SNP.

The scale of estimating speed, quality and quantity of processing visual information including 5 grades for the men aged 17-45, is offered to compare the individual differences of the main nervous processes and the features of reactions of sensorimotor functions (Table 2).

Table 2: Scales of estimating the level of speed, quality and quantity of processing visual information of different complexity in the individuals with normal auditory function and deprivation

Level of information processing	Speed of information processing		Quality and quantity of information processing	
	Feedback (s)		Feedback (number of signals)	
	Healthy	Deaf	Healthy	Deaf
High	≤54.0	≤61.1	≥850.6	≥740.1
Upper-Intermediate	54.1-60.4	66.2-62.4	785.3-849.2	675.2-739.1
Intermediate	60.5-69.1	71.3-67.1	678.2-784.4	568.2-674.3
Pre-Intermediate	69.2-75.9	76.1-72.2	631.1-677.4	521.2-567.5
Low	≥76.0	≥77.0	≤630.3	≤520.5

IV. CONCLUSION

It should be noted that the quantitative indicators of sensorimotor functions, speed, quality and quantity of processed visual information, FMNP and SNP levels obtained using devices and methods of other authors may be different from ours. It is due to the technical specifications, which are incorporated in the program. An analysis of a sufficient number of digital data received using different registering devices and manual processing of forms allowed us to make substantiated recommendations in the technical tasks concerning the abolition of corresponding measurements in some boundaries of response and time for accounting the correct answer that significantly expanded the range of individual differences between people. However, this issue requires more detailed presentation. The obtained data concerning the use of experimental results in different theoretical investigations including the study of their demonstration in neurophysiological, somatic-vegetative and psychomotor functions, the study of different sides of complete behaviour picture of the people with auditory deprivation and without it require a special presentation that will be presented in our subsequent works. Weemphasize that our study does not claim to have exhaustive results, and is an attempt to make a contribution to the understanding the biological basis of individual differences between them.

The results of comparing a set of indicators of processing visual information, main nervous processes with the estimation of efficiency of labour activity, success and effectiveness of education may find application in practical issues, scientific organization of labour, professional psycho-physiological selection, professional orientation of the people with auditory deprivation as the sensitive and objective indicators of brain capacity and the estimation of body functional state.

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