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DEVELOPMENT OF AN APPLIED INTELLECTUAL SYSTEM BASED ON NEUROPHYSIOLOGICAL DATA TO SUPPORT DECISION-MAKING IN THE ORGANIZATION OF THE EDUCATIONAL PROCESS

DESARROLLO DE UN SISTEMA INTELECTUAL APLICADO BASADO EN DATOS NEUROFISIOLÓGICOS PARA APOYAR LA TOMA DE DECISIONES EN LA ORGANIZACIÓN DEL PROCESO EDUCATIVO

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ABSTRACT

In modern science, one of the urgent problems is the search for ways to improve the teaching effectiveness. The study of neurophysiological patterns in the formation of individual variations of cognitive activity of students at various stages of ontogenesis is a condition for solving the problems of developing innovative technologies to improve the quality of the educational process. The paper describes the process of developing an applied intellectual system that allows using individual differences in cognitive activity of students and schoolchildren identified using neuroscience technologies. The use of methods and techniques of training organization is largely due to individual typological features that can be analyzed using neurobiological indicators. The individual neurophysiological profile express analysis characterizes behavioral aspects of cognitive activity. With the help of an intelligent system, a complex of neurophysiological indicators of groups of students was processed to identify the influence of learning conditions on these indicators. Based on the data sets obtained during the tests, the system forms the distribution of students into groups, project teams or pairs and recommends study activities depending on their neurophysiological profile.

Keywords:

Artificial intelligence, machine learning, applied intellectual system, neurophysiological profile, individual educational trajectory.

RESUMEN

En la ciencia moderna, uno de los problemas urgentes es la búsqueda de formas de mejorar la eficacia de la enseñanza. El estudio de patrones neurofisiológicos en la formación de variaciones individuales de la actividad cognitiva de los estudiantes en diversas etapas de la ontogénesis es una condición para resolver los problemas del desarrollo de tecnologías innovadoras para mejorar la calidad del proceso educativo. El artículo describe el proceso de desarrollo de un sistema intelectual aplicado que permite utilizar las diferencias individuales en la actividad cognitiva de estudiantes y escolares identificadas mediante tecnologías de neurociencia. El uso de métodos y técnicas de organización del entrenamiento se debe en gran medida a características tipológicas individuales que pueden analizarse mediante indicadores neurobiológicos. El análisis expreso del perfil neurofisiológico individual caracteriza los aspectos conductuales de la actividad cognitiva. Con la ayuda de un sistema inteligente, se procesó un complejo de indicadores neurofisiológicos de grupos de estudiantes para identificar la influencia de las condiciones de aprendizaje sobre estos indicadores. A partir de los conjuntos de datos obtenidos durante las pruebas, el sistema forma la distribución de los estudiantes en grupos, equipos de proyectos o parejas y recomienda actividades de estudio en función de su perfil neurofisiológico.

Palabras clave:

Inteligencia artificial, aprendizaje automático, sistema intelectual aplicado, perfil neurofisiológico, trayectoria educativa individual

INTRODUCTION

The National Strategy of Artificial Intelligence Development until 2030 is aimed at the development of artificial intelligence (AI) in the Russian Federation (President of the Russian Federation, 2019) and defines the concept of AI and its main directions development. The possibility of using an interdisciplinary approach and combining AI technologies, neuroscience technologies and educational technologies can contribute to solving one of the most important tasks of the Russian education system – improving the learning process efficiency.

We are developing an applied intellectual system that allows taking into account individual differences in students' and schoolchildren cognitive activity, identified using neuroscience technologies, and forming the distribution of students into groups, project teams or pairs based on the data sets obtained and recommending learning assignments. Thus, we can talk about individualization in the construction of an educational trajectory, a reasoned approach to the formation of teams and decision-making support in the educational process organization.

The current stage of artificial intelligence development, approaches to its definition, the state of work on artificial intelligence in Russia, threats to its use and future trends are presented in the paper. If we talk about the use of AI technologies in education, the GlobalData has listed artificial intelligence first in the list of technologies that have an impact on education (Edtech, 2021). For example, checking and evaluating completed academic assignments, setting up individual (personalized) training, help and support (for example, chatbots), mentoring, tracking progress and predicting educational problems.

AI technologies are widely used both in the organization of the educational process (Salas-Pilco & Yang, 2022; Shang et al., 2022), planning and management of the educational process (Hamim et al., 2022; Wang et al., 2022), formation of its methodology (Zhang, 2022) and as an object of study (Yagci, 2022).

Scientists note an increase in the efficiency of the educational process, an increase in the convenience of its organization (Titov, 2020; Amirov & Bilalova, 2022). Scientists have noted the influence of AI on the content of education and the difficulties and problems that arise in this regard (Karpukhin, 2019; Torosyan, 2019; Izmailova, 2020).

As examples of real implementations of artificial intelligence technologies in education, we can cite the online electronic learning system "01mathematics". The system uses adaptive learning based on neural networks and big data, building individual math training for schoolchildren. The use of adaptive learning in higher education is presented in the work (Bataev, 2019).

The use of artificial intelligence in customizing the matching of teams during events is successfully used by the University 2035. It also uses the analysis of the digital trace of the user, the analysis of the specifics of communication in audio in AI technologies, allowing to increase the efficiency of the team.

The development of AI in education is also being handled by the Center for Psychometrics and Measurements in Education, the HSE Institute of Education. For automatic generation of tasks for language literacy, an artificial neural network ruGPT-3L from the SberUniversity with 760 million parameters is used and its completion by Prompt Tuning.

MATERIALS AND METHODS

The formation of the data set is based on the results of the information system that collects and processes of neurodynamic indicators diagnostic data. The data determine the central nervous system integral characteristics and characterize the individual features of students and schoolchildren. The information system is called "Building students' individual neurophysiological profile". Determination of neurodynamic characteristics of 900 students who took part in the study was carried out using the hardware and software complex "NS-PsychoTest" ("NeuroSoft", Russia, Certificate of Conformity No. ROSS RU.IM18.D00567). The following methods were used in the examination: "Simple visual-motor reaction" (SVMR), Complex visual-motor reaction "Choice reaction" (CVMR), "Tapping test". The current functional state of the central nervous system (CNS) was determined by the criteria of T.D. Loskutova: functional level of the system (FLS), reaction stability (RS), functionality level (LF) (Mantrova, 2007; Moroz, 2007).

As an integral indicator of the functional state of the central nervous system, Bayguzhin & Shibkov (2017), consider the time of an arbitrary reaction. To do this, Moroz (2007), suggests considering the dynamic characteristics of the simple visual-motor reaction time (variational chronoreflexometry). The speed of sensorimotor response reflects the basic properties of the nervous system, in particular, excitability, reactivity and lability. In the context of educational and professional activity, the functional state of the central nervous system acts as an indicator of the course of the process of students' adaptation to the conditions of the educational environment.

According to the tests' results, the types of functioning of the nervous processes of students were determined by groups of indicators (activation, stability, endurance):

1. Activation: simple visual-motor reaction (average reaction time), complex visual-motor reaction (average reaction time).

2. Stability: simple visual-motor reaction (reaction stability), complex visual-motor reaction (Whipple coefficient – the complete assignment accuracy factor).

3. Endurance: the number points of 30 seconds tapping test.

RESULTS AND DISCUSSION

We have created a model of analyzing students' neurophysiological indicators to determine their neurophysiological type. There are six neurophysiological types: high, optimal, compensatory, asynchronous-limiting, low, indefinite. Each type is characterized by its own cognitive characteristics and, accordingly, the greatest effectiveness will be given by taking these data into account in the educational process.

The information system «Building students' individual neurophysiological profile» (Belousova et al., 2022) allows to download data after conducting tests of the NS-Psychotest complexes and it determines the neurophysiological profile. Next, the program generates recommendations for teachers, they can be uploaded in *.docx.

To use supervised machine learning technologies, a structured data set in csv format is formed based on the results of the program. It contains information about the test date, the educational organization, group or class, the student's last name, the first name, his or her neurophysiological type, the average score of the Unified State Exam/the Main State Exam and GPA, etc. The experts have developed rules and entered into the data set recommendations for combining neurophysiological types into teams (groups) or pairs for collaboration, recommendations on the types of educational assignments that one or another neurophysiological type successfully performs, as well as general recommendations for students' activities for each type. For the created model in the Python programming language, supervised learning takes place. There were 900 people in the sample at the beginning of the study, currently it is supplemented with new data, and annual data updates are planned to monitor the dynamics and effectiveness of the educational process organization.

Let's consider the features of the application system. When launching the program, you need to select an educational organization (the list includes organizations where testing took place, data is downloaded from the Data.csv file when the program is launched) and then select a university group or a school class. The list of groups/classes is generated automatically when choosing an educational organization and is also loaded from the Data.csv file.

By clicking on the «Upload data» button, data is automatically uploaded to the database from the Data.csv file. Since measurements will be carried out in the future, and the list of educational organizations will change, it is decided to the database's flexibly change. The file can only contain only one list of groups/classes for a specific educational organization and be provided to the user with updated data after new tests. Upon successful download, the user is given a message. Otherwise, an error message.

After downloading, the program analyzes the big picture of the group / class and there is a diagram of the types' quantitative characteristics. The teacher can read general recommendations for working with the group / class to organize front-line work, adapted for the educational process (Figure 1).

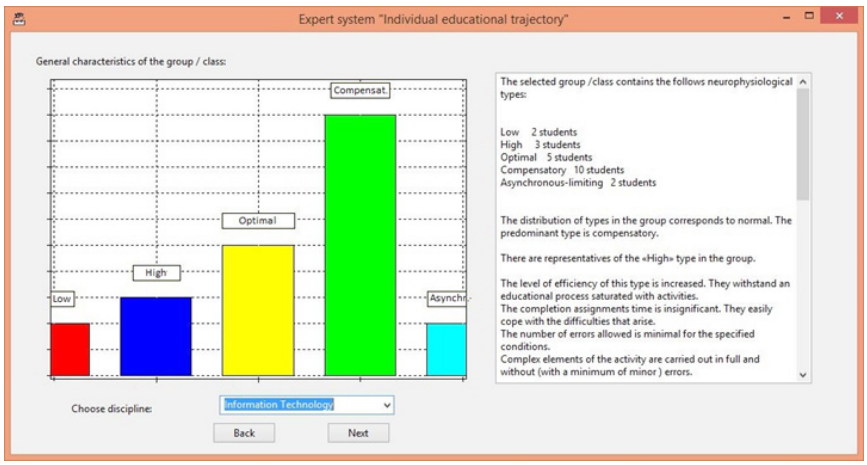

Figure 1. General characteristics of the group/class.

The main types' characteristics on the basis of which the recommendations were developed are partially presented in Table 1 (Belousova et al., 2021).

Table 1. Characteristics of neurophysiological types.

Type	Characteristic
High	The increased efficiency level. The insignificant learning assignment completion time. The minimal allowed errors number for the specified conditions. Complex elements of the activity are carried out in full and without (or with a minimum of minor) errors. Can perform complex types of tasks, including those requiring high concentration of attention
Optimal	The optimal efficiency level. The optimal learning assignment completion time. The optimal allowed errors number for the specified conditions. Complex elements of the activity are carried out in full and without (or with a minimum of minor) errors.
Compensatory	The level of working capacity is slightly reduced (usually the lower limit of the age-sex norm). There will be fatigue under the influence of exerting loads. Reflects the increasing stress during prolonged operation. The activity effectiveness as a whole corresponds to the specified parameters of the activity performance. Medium-reduced endurance indicators
Asynchro-nous-limiting	The reduced efficiency level. The assignment execution time can vary in a wide range (very fast or very slow). Unbalanced nervous processes. Excessive nervous and emotional tension may develop in the process of work. The optimal working time is a short time. It is characterized by a lot of errors with a minimum activity execution time. It can be mobilized at the beginning of the work, but over time the quality significantly decreases

At the bottom of the window, the user can select a discipline by selecting from the drop-down list. The list of disciplines is formed depending on the curriculum for the group/class of the previously selected educational organization. At any time, you can return to the previous form by clicking on the "Back" button or continue working by clicking on the "Next" button.

The user can select a topic from the list provided for the previously specified discipline in the next window (Figure 2). The list of topics is formed on the basis of thematic planning. The program uses a previously trained model. And when choosing the study activities, it offers a students' team/pair division based on compatibility and maximum efficiency of neurophysiological types' collaboration (example in Table 2), similarity or difference in academic performance, and also offers a selection of learning assignments which is optimal for the team/pair (example in Table 3).

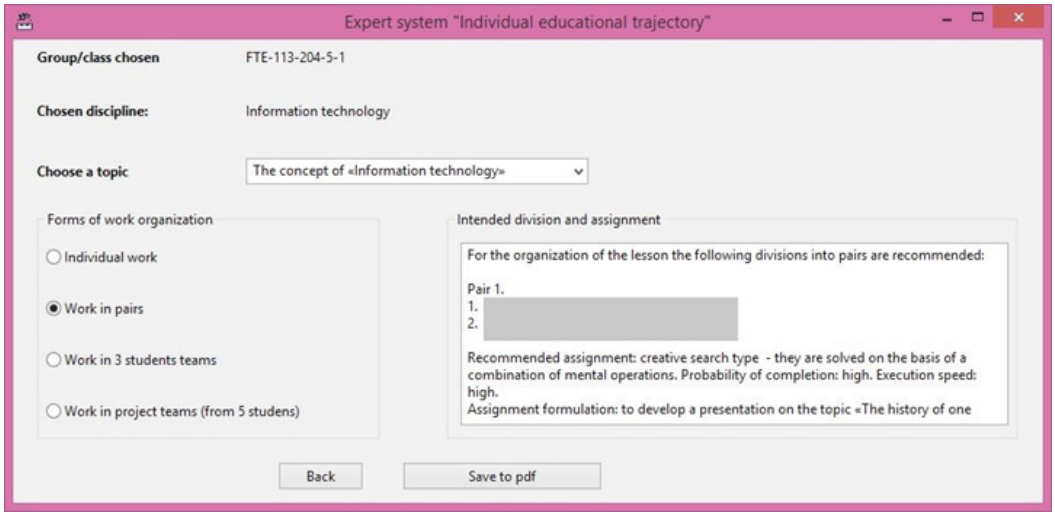

Figure 2. Learning assignments viewing.

The information is updated when the form of work organization changes. To change the discipline, you need to return to the previous window by clicking the "Back" button. You can also save the expected teams division and assignments

in *.pdf format by clicking on the “Save to pdf” button. The system indicates in the file header the selected group/class, the specified disciplines and topic, then form a list of students’ divisions and upload an example of an individual assignments for each student or team/pair, depending on their types (Figure 3).

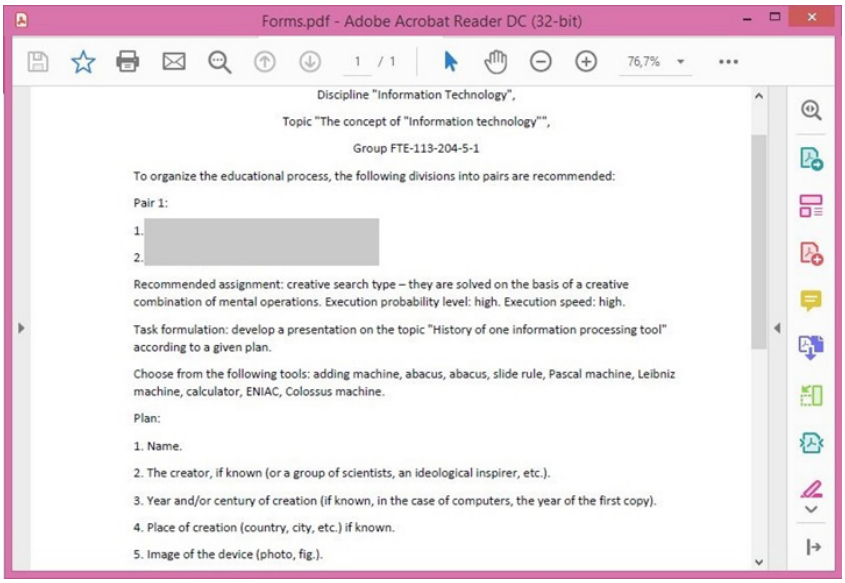

Figure 3. Example of an assignments file.

If necessary, user can link the file names of illustrations, audio and video files in the text. The files can be stored in the folder “Data” in the program.

Table 2. A fragment of the rules for optimal interaction of types in a pair/team.

Optimal composition of the group/team	Low	High	Compensatory	Optimal	Asynchronous-limiting
Option 1		+	+	+	
Option 2	+		+	+	
Option 3			+	+	

For example, the verbal formulation of the rules for teams’ division was as follows: when organizing the cognitive activity in pairs, a high or optimal neurophysiological type is combined with the others. It is desirable to combine a low type with a compensatory one. An asynchronous-limiting type will give poor performance in pairs, since it has a multidirectional nature of cognitive activity combined with rapid fatigue. The leading role will be better performed by a high or optimal type. An asynchronous-limiting type and a low type will usually be passive in the team and shift their roles to other team members. In this case, a requirement of duties separation and a report on their implementation is required. Basically, the role of active performers in the group is performed by the compensatory type of students. There must be a maximum one an asynchronous-limiting type representative in the team. Conflicts can arise between high and optimal types, low and high, and asynchronous-limiting – with all types.

Table 3. A fragment of the rules for learning assignments selecting.

Type	Learning assignment type	Execution time	Can work in pairs	Can work in a team	More effective role in a team
Low	Reproductive and/or algorithmic For example, a closed-type test, an text question answer, etc.	For a long time	Yes	Yes/no	Executor
High	All types: reproductive, algorithmic, transformational and creative-search	Optimal	Yes	Yes	Leader

Compensatory	Reproductive, algorithmic, transformational (+-)	Closer to optimal	Yes	Yes	Executor
Optimal	All types: reproductive, algorithmic, transformational and creative-search	Optimal	Yes	Yes	Leader
Asynchronous-limiting	Reproductive and/or creative search	Either extremely long, or extremely fast	No	No	Executor

To update the assignments and activities database, a variant of the program with expert mode is provided. The expert launches the program and selects an educational organization in the main window of the program, groups/classes and disciplines are loaded in the list for the educational organization, and a list of topics for disciplines. If there is no discipline or topic, you can add them by entering the name in the appropriate field and clicking on the "Add" button. The program checks whether the entered name exists and, if it is new, adds it to the list. In case of successful addition, a message is displayed, otherwise - an error warning.

After selecting all the fields and clicking the «Next» button, the expert can specify the neurophysiological type and enter the text or paste it from the clipboard into the appropriate field.

If it is needed to add images, audio and video files, you can do this by clicking on the «Attach file(s)» button. If the task is posted on the Internet, you can insert a link. Upon completion, you need to click the «Save» button. Upon successful data entry, a message is showed to the user. After that all updates are saved to the Task.csv file and can be send to end users to update the database.

When forming assignments and study activities differentiated for each neurophysiological type, in the work of an expert, we maintain the logic of discipline, take into account the requirements of Federal Educational Standards, while each student will be optimally selected the volume of assignments, their content, a set of different types of activities that are most effective for a given neurophysiological psychotype.

CONCLUSIONS

The prospects of the applied solution consist in the development of a students' feedback program based on the results of the teams/pairs division and the completion of proposed assignments and activities. This information will allow to evaluate the model's effectiveness, take into account new trends and improve the training process of the model. After receiving and accumulating feedback in data sets, pedagogical forecasting becomes possible. It consists in searching in the history of the advancement of a student similar to him (by neurophysiological type, gender, academic performance), but younger in age and the opportunity to offer the younger a more effective educational route, taking into account errors in the elder's promotion.

When developing the system, the basic principles of the development and use of artificial intelligence are taken into account, such as transparency when choosing the process of dividing pairs and students' teams and the criteria for selecting assignments, so the so-called weak artificial intelligence, supervised machine learning is used.

Undoubtedly, the most valuable thing in the educational process remains the personal work of the teacher and the student, their direct and live communication. In this case, the work of the system, predictive analytics works on the principle of security and protection of human rights and freedoms. It is the teacher who are the ultimate organizers of interaction and can adapt the program's proposed students's dividings, make changes to the sets of training assignments or provide students with distribution into teams at will. In this case, the teacher retains control and controllability of the process, the so-called «humanity» is provided.

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