

# Psychophysiological Predictors of Preservation of Students' Health under Examination Stress

N.A. Belousova, V.P. Maltsev, Yu.V. Korchemkina

South Ural State Humanitarian Pedagogical University, Lenin Avenue, 69, Chelyabinsk

## Abstract

**Problem and objective.** The design of an individual educational trajectory with due account for the individual characteristics of cognitive processes is relevant in modern education. The objective of the study was to organize the students' cognitive activity in the conditions of the examination load, taking into account the psychophysiological profile as a criterion of health preservation.

**Materials and methods.** The study involved 114 first-year female students aged 17-18 studying at the Faculty of Training Elementary School Teachers of the South Ural State Humanitarian and Pedagogical University in Chelyabinsk. The general sample was randomly differentiated into the main group (Group 1, n=61), for which the program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" was implemented, and the control group (Group 2, n=53), where traditional tests were performed. The diagnostics of the level of mental performance by the parameters of a simple visual-motor reaction was performed using a hardware-software package "Biomys" (Biomouse) (NeuroLab, Moscow). The situational and trait anxiety was assessed. The mathematical-statistical analysis was conducted with the use of Microsoft Excel and Statistica v. 7.0.

**Results.** The population of students at the control stage of the study was characterized by an average level of mobility of nervous processes, an optimal speed of the nervous system, a moderate degree of trait and state anxiety. Upon the program completion, the students of the main group noted an increase in the average group indicator of the CNS reaction stability at high values of the reaction stability and reliability of the activity. No significant differences in the mean values of sensorimotor reactions of students in the studied groups have been identified. The indicators of state anxiety had a regular increase in mean values in both groups, but an increase in the mean value of the control group by an indicator of state anxiety was 3.5 times higher than that in the main group.

**Conclusion.** Task scheduling with the use of the program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" makes it possible to improve academic performance with relatively constant rates of state and trait anxiety, and thus to ensure students' stable psychoemotional state as one of the conditions for health preservation.

**Keywords:** educational trajectory, students, examination stress, sensorimotor reactions, mental performance.

## INTRODUCTION

Problem statement. The Federal State Standard of Basic General Education adopted in 2010 has regulated the design of the educational process in the context of the system-activity approach, taking into account students' age, psychological and individual-typological peculiarities. In the available literature, there is enough material on the design and implementation of an individual educational trajectory with due account for students' psychological characteristics [1-3]. In modern pedagogy, the design of an individual educational trajectory as a personal way of a student's self-fulfillment is based on the psychological-didactic approach [4-6]. An individual educational trajectory is determined by the nature of the method of training activity [7].

The concept of an individual educational trajectory came to pedagogy from physics; this trajectory is implemented in the educational environment in the content, activity and procedural aspects. In the available literature, conditions and resources for implementing an individual educational trajectory for different groups of students are highlighted [8, 9].

There are examples of design of an individual educational trajectory based on a type of personal orientation in accordance with the leading component of thinking [10, 11]. A number of authors developing this area of research [12, 13] consider the issue from the standpoint of the personal paradigm: individual personal qualities that determine the orientation toward learning and approaches to learning are predictors of the success of training.

The design of an individual educational trajectory is often associated with the psychological concept of "training styles" or "cognitive styles", which are stable individual peculiarities of cognitive processes. Sysoev [14] highlights up to 15 cognitive styles.

Within the framework of the criterion-oriented approach, Bespalko proposed taxonomy in the form of levels of information processing: recognition, reproduction, understanding, application, possession [15]. The authors have specified five hierarchical sublevels of the basic conceptual-aspect criterion, indicated the types of tasks of recognition, reproduction,

understanding as a level of knowledge. The tasks offered to students correspond to three levels of complexity: know, be able, master.

Personal characteristics are the result of manifestation of individual-typological features; therefore, in the authors' opinion, it would be interesting to be based on students' psychophysiological status in the design of an individual educational trajectory. The indicators of mental performance based on psychophysiological testing can be used for the objective assessment of cognitive processes.

In the context of the paradigm of modern education, the very concept of the teacher's training has changed: from a teacher-performer to a teacher-researcher [16]. As noted by Sutherland and Markauskaite [17], the leading role in the concept of professional identity is given to the authentic component of training. The discipline "Developmental Anatomy, Physiology and Hygiene" is included in the curriculum in the field of study 44.03.01, 44.05.01 Pedagogical Education of Any Profession Orientation. The content of this discipline allows students to master the following competencies: the ability to provide training, education and development, taking into account social, age, psychophysical and individual peculiarities, including specific educational needs of students; readiness to ensure the safety of students' life and promotion of their health. The discipline "Developmental Anatomy, Physiology and Hygiene" has many research tools; students master anthropometric and physiometric research methods to study and apply them in the pedagogical activity, these methods allow determining the correspondence of the students' development level to age. They will learn to characterize the properties of nervous processes, plan an adequate diet of schoolchildren, establish the compliance of physical activity with the functional state of the cardiorespiratory system.

The authors have proposed the program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile", in which prognostic indicators of the effectiveness of performing tasks of different cognitive complexity based on students' psychophysiological state are developed.

The objective was to organize the students' cognitive activity in conditions of examination load, taking into account the psychophysiological profile as a criterion of health preservation.

**Materials and methods.** First-year students of the Faculty of Training Primary School Teachers of the South Ural State Humanitarian and Pedagogical University in Chelyabinsk took part in the study. A total of 114 female students aged 17-18 were examined. The general sample was randomly differentiated into the main group (Group 1, n=61) and control group (Group 2, n=53) of students.

The program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" was implemented for the students of the main group. Students' psychophysiological features were studied, based on which the levels of tasks were subsequently designed. The control group consisted of students, who performed examination tasks upon the traditional program of university disciplines. All participants in the study were previously informed about the conditions, procedure and algorithm of the program implementation.

The diagnostics of students' psychophysiological traits was performed using a hardware-software package "Biomysh" (Biomouse) (NeuroLab, Moscow). The express assessment of the functional state of the central nervous system and the level of mental capacity was performed by the parameters of a simple visual-motor reaction (SVMR).

The diagnostics of the psychoemotional state was performed applying the method of subjective assessment of state and trait anxiety by Spielberger and Khanin. The survey was conducted on a voluntary basis, with the written informed consent of participants in pedagogical research.

The mathematical-statistical analysis of the obtained results of the surveyed students was carried out using software Microsoft Excel and Statistica v. 7.0.

The data analysis was carried out based on mathematical calculations with the computation of an arithmetic mean (M), and an error of the arithmetic mean (m). Fisher's F-criterion of one-way ANOVA was used to assess the reliability of differences in mean values of the indicators of the groups compared. The homogeneity of variances of the indicator studied in two groups was estimated by using the data of Levene's test. In case of different variances of the studied trait, as well as for comparing the reliability of the mean shift, the analysis was performed using Student's t-test. The comparison of empirical frequency values was carried out using a criterion of homogeneity of the chi-squared distribution ( $\chi^2$ ). The results at  $p < 0.05$  were considered statistically significant.

## RESULTS AND DISCUSSION

The students of the main group were offered the examination tasks based on the program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile", which allowed selecting the level of task complexity based on the established psychophysiological status.

To implement this program, in the context of monitoring the level of students' competence, theoretical and practical tasks on developmental anatomy and physiology have been developed: test tasks of different levels of complexity and situational tasks (case studies). Variants of tasks were interpreted based on the taxonomy of tasks by B. Bloom's followers [18], compiled on the basis of classification of levels of thinking. The taxonomy of mental abilities allowed classifying tasks by types: to know (learn, recall, cite examples, interpret, classify, compare explanations, generalize), to be able (use the procedure in a new situation), to master (analyze, assess (make judgments based on criteria and standards)), to create (integrate parts into a single whole) [15].

Test tasks are structured according to the level system, depending on the complexity. First, tasks with one response

option were provided, then tests with the choice of several correct answers, tasks on correspondence and correct sequence were grouped. Case studies correspond to the subject area of an academic discipline and are practice-oriented, relevant for the organization of students' educational activities, have a minimum level of content of artificiality and abstraction [19]. Thus, the first group of tasks (of theoretical content) is used to verify the assimilation of knowledge at the following levels: recognition, memorization, understanding. The second group of tasks is used to check the ability to apply knowledge based on algorithmic prescriptions. The third group of tasks is used to check the ability to apply knowledge in an unusual situation.

To simplify the selection of tasks, based on the MSAccess database management system, the authors designed and created a database of tasks on the discipline "Developmental Anatomy, Physiology and Hygiene"; the content of tasks corresponds to the above-described test booklet on this discipline. The database has a simple interface for interacting with users (a teacher and students), which allows selecting tasks for students on specific topics based on the indicators of the performance level. A large database of tasks allows creating different samples of similar tasks, constructing task sets in different sequences, which contributes to the objective assessment of students' knowledge and skills.

Based on the theoretical and practical studies of the application of psychophysiological diagnostics as a criterion for the objective assessment of individual cognitive processes and a tool for dynamic control of the level of mental efficiency of students at various stages of educational activity, the authors proposed a model for designing the educational trajectory of a student with due account for the psychophysiological profile. A detailed description of the model for designing the educational trajectory of a student with due account for the psychophysiological profile is described in the work [20].

The program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" allows not only choosing the level of task complexity based on the psychophysiological state but also limiting the performance time and evaluating the tasks of "know" and "be able" levels. Tasks for acquiring knowledge are assessed by a teacher in points, while the results are typed into the program.

A simple sensorimotor reaction to a visual stimulus (a simple visual-motor reaction (SVMR)) allows diagnosing one of the leading properties of the nervous system – the mobility of nervous processes, which characterizes the velocity of nerve impulse conduction through the elements of the reflex arc. The test for determining the velocity of a simple visual-motor reaction can be considered as an integral characteristic of the human CNS, since this activates the two leading sensory systems.

Within the framework of the ascertaining stage of the study, the authors performed the diagnostics of the background level of students' psychophysiological indicators. In order to avoid a negative influence of environmental factors, the survey was conducted during the intersessional period, in the first half of the day, within the framework of classes after the stage of adaptation to the educational process of the university (in October).

As is known [21], the functional state is dependent on the activation of central elements of the nervous system in a certain period of time. The functional state of the body depends on the characteristics of nervous processes and determines the level of performance of a person, the limits of his/her capabilities at that time. Sensory-motor consistency occurs at different levels of the brain and, according to the studies [22, 23], is a marker of the functional state of the CNS.

The most effective mental activity of a person is noted in the normal functional state of the CNS that corresponds to the

physiologically optimal level of activation of the nervous system in a state of wakefulness [24]. In connection with the above, the program design is based on the study of integral characteristics of the CNS with the use of computerized instant diagnostics of variational chronoreflexometry.

The comparison of the average results of the sample with the reference values indicates the average level of mobility of nervous processes; the velocity of the nervous system of the group of students under study is optimal (the mean value is  $224.7 \pm 1.9$  ms). The average level of mobility of nervous processes characterizes the optimal switching of attention from one activity to another, which is convincingly proved by the neurophysiological study of the dynamic relationship between the sensorimotor integration and cognitive systems of information analysis [25].

The relative homogeneity of the studied indicator of SVMR among students of both groups indicates the homogeneity of the sample of the surveyed by the indicator and the acceptability of differentiation into groups within the framework of this study.

The obtained results of the study of the background psychophysiological state of female students testify to the optimal functional state of visual and somatosensory analyzers of the surveyed students. The calculation criteria, reflecting cognitive performance capabilities, diagnose the high functional state of the CNS of first-year female students.

The mental capacity of the surveyed group of students was assessed on Loskutova's design criteria of SVMR: the functional level of the system (FLS), reaction stability (RS), and the functionality level (FL). The analysis of the data in the table characterizes high indicators of the overall functional state (the mean value of FLS is  $5.0 \pm 0.05$  standard units) and the functionality level (the mean value of FL is  $5.2 \pm 0.08$  standard units) with an average level of intensity of the reaction stability (the mean value of RS is  $2.5 \pm 0.07$  standard units), which reflects the high functional status of the CNS of the surveyed female students. At the same time, the high average indicators of FLS and FL of students in both groups reflect the prevalence of excitatory processes in the CNS [26]. The obtained results characterize the adaptive mechanisms of the CNS response and indicate an increase in the functional level of an adequate executive functional system of the surveyed group of students that meets the needs of this cognitive activity.

The background indicators of state and trait anxiety characterize favorable psychoemotional state of female students at the time of the survey, which indicates the optimal functioning of the nervous system and can be considered as a criterion for the qualitative organization of the educational process and the success of the stage of social adaptation of students to high school conditions.

According to the studies conducted by Moroz, the indicators of the stability of the nervous reaction (RS) serve as a functional criterion of the level of mental performance, reflecting the early functional changes in the activity of the CNS. The frequency distribution of the studied indicator of RS corresponds to the law of normal distribution and states the predominance of individuals with average values of the indicator (46.5%), with relatively equal frequency distributions with low and high values (24.5% and 28.9% respectively). No reliable intergroup differences have been identified.

The reliability of activity is characterized by the frequency of erroneous reactions during the testing of SVMR, which manifests itself in signal skipping and untimely clicks. The obtained results ( $94.9 \pm 1.5$  standard units) indicate high indicators of reliability of activity (about 95%) during sensorimotor testing, which agrees with the above values of the indices of the functional state of students' CNS.

State anxiety is the level of anxiety in specific environmental conditions; trait anxiety is a psychological property of a person. The population of students is characterized by an average level of anxiety, both state and trait anxiety. It is important to note that the average level of intensity of state anxiety ( $33.6 \pm 0.9$  standard units) is significantly lower by 15.5% ( $t=4.53$ ,  $p<0.001$ ) of the same value of the indicator of trait anxiety ( $38.8 \pm 0.7$  standard units), which points indirectly to favorable conditions for the survey.

Analyzing the percentage distribution of the surveyed students of the general sample by indicators of the psychoemotional sphere, it can be concluded that the majority of the surveyed female students had a moderate degree of trait and state anxiety (68.4% and 50.9% respectively), with the low incidence of high anxiety (16.7% – trait anxiety, 7% – state anxiety). A low degree of trait anxiety was found in 14.9% of the sample of female students, state anxiety – in 48.1% of the sample.

After the implementation of the program of planning of an individual educational trajectory based on the psychophysiological status data, the average parameters of sensorimotor reactions and the psychoemotional sphere of female students had the following values (see Table 1).

The analysis of tabular data allowed revealing intergroup differences in integral indicators of the psychophysiological and psychoemotional profile of students' personality. It should be noted that upon the program completion, the students of the first group were characterized by an increase in the mean group indicator of the CNS response stability ( $t=-2.62$ ,  $p=0.01$ ), with a relatively stable high activity reliability (on average over 95%,  $t=2.61$ ,  $p=0.01$ ).

Table 1 Average parameters of sensorimotor reactions and psychoemotional sphere of students

Parameters		Group 1 (n=61)	Group 2 (n=53)	p-level
Simple visual-motor reaction, ms	M $\pm$ m	223.3 $\pm$ 2.6	226.3 $\pm$ 2.7	-
	shift, %	<1	<1	
Reaction stability, standard unit	M $\pm$ m	2.6 $\pm$ 0.10	2.4 $\pm$ 0.10	< 0.001
	shift, %	7.7*	-14.6**	
Reliability of activity, %	M $\pm$ m	95.9 $\pm$ 1.6	93.9 $\pm$ 1.5	< 0.001
	shift, %	1.5	-7.2**	
State anxiety, standard unit	M $\pm$ m	34.1 $\pm$ 1.1	33.1 $\pm$ 1.	< 0.001
	shift, %	9.7**	34.4**	

Note: p-level – reliability of intergroup differences; \* – reliability of the indicator shift ( $p<0.01$ ), \*\* – reliability of the indicator shift ( $p<0.001$ ).

In the control group, a significant decrease in the mean group indicator of RS was observed on average by 15% ( $t=3.57$ ,  $p<0.001$ ) with a combined increase in the number of failing responses when testing (a reliable decrease in the mean group indicator of reliability of activity by 7.2% ( $t=3.96$ ;  $p<0.001$ )). The mean values of RS and reliability of activity were significantly higher in the first survey group ( $F=33.09$  and  $F=17.10$ ,  $p<0.001$  respectively).

The indicators of state anxiety upon completion of the control procedure had a regular increase in the mean values in both groups ( $t_{1gr}=-4.14$ ;  $p<0.001$ ;  $t_{2gr}=-5.04$ ;  $p<0.001$ ). However, an increase in the average indicator of the control group by the indicator of state anxiety was 3.5 times higher than the same values of the indicator of the first group ( $F=11.94$ ,  $p<0.001$ ).

Attention is drawn to the relative stability of the mean values of students' sensorimotor reactions, regardless of the group affiliation (see Table 2): a change in the mean values at the end of the experiment did not exceed 1% ( $t_{1gr}=0.82$ ;  $p>0.05$ ;  $t_{2gr}=-0.83$ ;  $p>0.05$ ). There were no significant differences between the main and control groups ( $F=1.98$ ,  $df=112$ ,  $p=0.16$ ).

Table 2 Frequency distribution according to the level of psychophysiological indicators in the survey groups, %

Indicators	Level of the indicator			$\chi^2$ , p-level
	Inactivity	Average	Mobility	
SVMR				$\chi^2=7.09$ p=0.03
Group 1	18	57	25	
Group 2	36	34	30	
Reaction stability	Low	Average	High	$\chi^2=18.07$ p=0.0001
Group 1	11	56	33	
Group 2	47	36	17	
State anxiety	Low	Average	High	$\chi^2=10.51$ p=0.005
Group 1	15	66	19	
Group 2	6	47	47	

However, with the similar manifestation of the mean values of SVMR, a qualitative analysis of the distribution of manifestation of mobility of nervous processes of the surveyed female students revealed a number of peculiarities. After the program implementation, the distribution of students under the law of normal distribution was noted in the main group, while in the control group there was a significantly higher number of students with inert manifestations of this physiological property of the nervous system ( $\chi^2=7.09$ , p=0.03) due to reduced the number of students with an average level of mobility of nervous processes.

Similar heterogeneous distributions ( $\chi^2=18.07$ , p=0.0001) were also fixed in indicators of levels of students' working efficiency by the criterion of RS. Thus, in particular, the number of female students with the average manifestation of the characteristic was prevalent in the main group, with the prevalence of students with high values of the level (more than 30% of the sample). In the control group, upon the completion of the standardized control program, the prevalence of students with a low level of mental performance was noted. The above distribution is consistent with the average group numerical values of the characteristic.

The distribution of students by indicators of the psychoemotional sphere had significant differences ( $\chi^2=10.51$ , p=0.005). In the control group, the number of students with an average and high level of state anxiety was equal to each other and in aggregate it was characteristic of more than 90% of the surveyed. While in the main group, after the implementation of the control program, the prevailing number of students was characterized by an average level of this psychological quality (about two-thirds of the sample), a high level was characteristic of only 1/5 of the sample of students in Group 1.

Intergroup differences in integral indicators of the psychophysiological and psychoemotional profile of female students after the program implementation are due to a reliably stable increase in psychoemotional stress of students in the control group. An increase in psychoemotional stress during an exam is described in a number of scientific papers and reflects the general biological regularity of increased emotional discomfort [27], the tension of neurovegetative regulatory mechanisms [28, 29], hormonal changes [30, 31], imbalance of the functional state of the CNS [32], changes in the immune component in response to mental stress [33]. State anxiety occurs as a person's reaction to various, most often socio-psychological, stressors as an expectation of a negative assessment, perception of an unfavorable attitude toward oneself.

Changes in the values of reactivity of female students of the control group are consistent with the imbalance in the emotional state and reflect an increase in the compensatory-adaptive mechanisms of neurohumoral regulation of the functional state of the body [28, 32]. The maintenance of cognitive activity in the conditions of examination load without taking into account the psychophysiological profile leads to an

increase in the excitability of the nervous system, which is reflected in a decrease in the reliability of activity (an increase in failing reactions) or the manifestation of inhibitory processes of the CNS – an increase in the number of students with inert manifestations of sensorimotor reactions. The duality of changes in the reactivity of students of the control group under examination stress reflects individual and typological peculiarities of the students' organism. In this case, according to Alexandrovsky [34], manifestations of inertness of nervous processes that ensure a decrease in noise immunity and an increase in the duration of sensory information processing act as the initial link of the dysfunction of the individual mental activity.

In the authors' opinion, the dynamics of good academic performance are an additional criterion for the effectiveness of the program. Good academic performance in the current study corresponds to the coefficient of competence formation on the learnt subject not less than 0.7.

Good academic performance in the control group corresponded to the coefficient 0.63, while only 26% of female students had a formation coefficient equal to or over 0.7. Good academic performance in the main group was 0.74, while more than half of the students (56% of the sample) were diagnosed with a high coefficient of competences' formation. The obtained results testify to the greater effectiveness ( $\chi^2=10.00$ ; p=0.002) of task performance in the program implementation in the main group of students.

#### CONCLUSION

Designing an individual educational trajectory based on the psychological-didactic approach takes into account the personal orientation.

The article presents a version of the integrated application of knowledge on psychophysiology, pedagogy in terms of informatization of the educational space. In particular, a computerized program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" has been proposed; it serves as a tool for organizing the final control of students' knowledge and skills, which allows diagnosing the psychophysiological state and, on its basis, selecting the level of task complexity, limiting the performance time and assessing tasks of "know" and "be able" levels. In this regard, the psychophysiological indices of a person can be considered as the prognostic parameters of the success of the cognitive activity. The preservation of the optimal psychophysiological state in the majority of students of the main group after the examination, as well as a significant increase in good academic performance, convincingly prove the effectiveness of the application of the program "Design of Students' Educational Trajectory Based on the Psychophysiological Profile" in the educational process. It should be noted that a fundamental principle of modern education (health preservation) has been successfully put into practice during the program implementation. The differentiation of complexity of verification tasks depending on the psychophysiological state is justified not so much by the need to improve the quality and effectiveness of education, but primarily by the need to preserve the resource capabilities of integrative systems and students' health in general.

Thus, it can be said with confidence that the design of an individual educational trajectory based on a conceptual-aspect criterion with due account for stable individual characteristics of cognitive processes is one of the important factors of health-saving education.

#### ACKNOWLEDGMENTS

This work was performed with the financial support of the FSBEI HE "M.E. Evseev Mordovian State Pedagogical Institute" under R&D Contract 1/331 of June 4, 2018 on the topic: "Construction

and Implementation of the Educational Trajectory of Individual Groups of Students Based on the Psychophysiological Profile".

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