ORIGINAL RESEARCH

Submitted: 15.01.2020; Accepted: 25.02.2020; Published online: 21.05.2020

With the financial support of the Russian Foundation for Basic Research, project No. 18 - 29 - 02073 "Digital medicine in the tasks of monitoring the psychophysical state of a person"

Cardio-oculometric indicators of psychophysiological readiness of students to examinations

Vladimir A. Zernov[1], Elena V. Lobanova[1], Elvira V. Likhacheva[1], Lyubov P. Nikolaeva[1], Diana D. Dymarchuk[1], Denis S. Yesenin[1], Nikita V. Mizin[1], Aleksandr S. Ognev[1]*, Mikhail Y. Rudenko[1], Natalia Y. Galoi[1], Anna R. Sudarikova[1]

[1] Russian New University
Russia 105005, Moscow, Radio str., 22
* Corresponding author:
e-mail: altognev@mail.com

Abstract

Cardio-oculometric indicators to grade psychophysiological readiness of students to examinations are described herein. Given is an experimental evidence that transitions from a low level of psychophysiological readiness of students to examinations to a high level of such readiness thereto is really accompanied by significant changes in the organism performance, first of all, in that of the heart. It is shown that a reliable marker of such changes is the heart rate variability assessment using the Baevsky stress index (SI), as well as the oculometric peculiarities of response to the visual stimuli, which students associate with their upcoming examinations.

Keywords

Cardiometry, Heart rate variability, Baevsky stress index, Psychophysiological readiness, Examinations, Unified state examination (USE), Eyetracking, Stress tolerance, Autonomic coefficient, Total deviation from the Lüscher-Valneffer autogenic norm

Imprint

Vladimir A. Zernov, Elena V. Lobanova, Elvira V. Likhacheva, Lyubov P. Nikolaeva, Diana D. Dymarchuk, Denis S. Yesenin, Nikita V. Mizin, Aleksandr S. Ognev, Mikhail Y. Rudenko, Natalia Y. Galoi, Anna R. Sudarikova. Cardio-oculometric indicators of psychophysiological readiness of students to examinations. Cardiometry; Issue 16; May 2020; p.28-34; DOI: 10.12710/cardiometry.2020.16.2834; Available from: http://www.cardiometry.net/issues/no16-may-2020/cardio-oculometric-indicators

Introduction

Academic examinations are one of the repetitive stress stages in life of a modern individual. As a rule, when preparing to examinations, the highest attention is focused on the cognitive component of an individual's readiness, which relates to either a demonstration of a specific knowledge or skills of applying the knowledge in practice. But at the same time, a psychophysiological state of an individual, which is the most important component of his/her readiness to the examinations of any type, often falls beyond the scope of the focused training and is out of sight for researchers of such trainings. In this respect, even the unified state examination (USE), which is an object for stormy public and political debates, is not an exception. It seems to be at least strange against the background of tens of thousands of investigations in the field of pedagogy and sociology, which try to prove the effectiveness of the above form of knowledge assessment, considering its importance for education system and students' training. Besides, in the early years of the USE introduction, sometimes appeared some works of psychologists with their recommendations on how students should improve the effectiveness of their preparation for examinations, but now such recommendations have been replaced by polemical notes of supporters of either negative or positive attitude towards these examinations.

It is also surprising that the issues of influence of the personological characteristics of the student as a subject in the educational activity on his/her effectiveness of coping with stress of such kind remain still insufficiently studied. But without studying the above issues, all programs of psychophysiological training to examinations become impersonal. In this case, the programs tend to formulate a set of some general-purpose guidelines, which are based, at best, on just a common sense and life experience. Their justification and possible adjustment still require a more in-depth study of relation of psychophysiological readiness and personal characteristics of the students with their success in overcoming examinations.

To a large extent, the reason for this lack of attention to the psychophysiological component of the students' readiness to examinations is the absence of reliable means to measure this decisive component. However, taking into account our studies described earlier [1-

12], we may assume that PC-assisted cardiographs of the Cardiocode type and modern portable eyetrackers can serve as the above mentioned measuring instrumentation. Our hypothesis takes into consideration the fact that, as shown in [1-4, 6, 8, 12], Cardiocode makes it possible to identify the nature of the respondents' affective response to certain stimuli using heart rate variability and Baevsky stress index (SI). Eyetrackers can also be successfully employed in evaluating the personal characteristics of respondents [13]. In addition, we demonstrate in [2, 11, 12] that the level and the nature of the respondent's stress reactions to visual stimuli can also be estimated based on oculographic data using the autonomic coefficient by Shiposh (AC) and the total deviation from the autogenic norm (TD) calculated on the basis of the Lüscher color test [15].

Materials and methods

To test the above hypothesis in the first part of our study, a complete set of subtest visual stimuli prepared as on paper sheets of the A-4 format, contained images as listed below, has been given to respondents:

toothy jaws of an attacking vampire bat;

a pretty image of a giant panda;

a huge spider devouring a wasp;

a rattlesnake preparing to attack;

a funny kitten playing around;

150-point typed word EXAMINATION;

190-point typed word SESSION;

a standard form of answers, which is used during the USE procedure.

During an alternate demonstration of each stimulus to respondent for 15 seconds an ECG has been recorded with the CARDIOCODE device, which allows an automatic calculation of Baevsky stress index (SI) values.

In the second part of the experiment, the above visual stimuli have been presented individually to each respondent on the screen of the GP-3 portable eyetracker. The complete set of the stimuli included the following images in this case:

110-point typed words GOOD MOOD surrounded by eight color squares from the Lüscher test;

150-point typed words EXAMINATIONS surrounded by eight color squares from the Lüscher test;

190-point typed word SESSION surrounded by eight color squares from the Lüscher test;

located in the same places, eight color squares from the Lüscher test without any other images or wording;

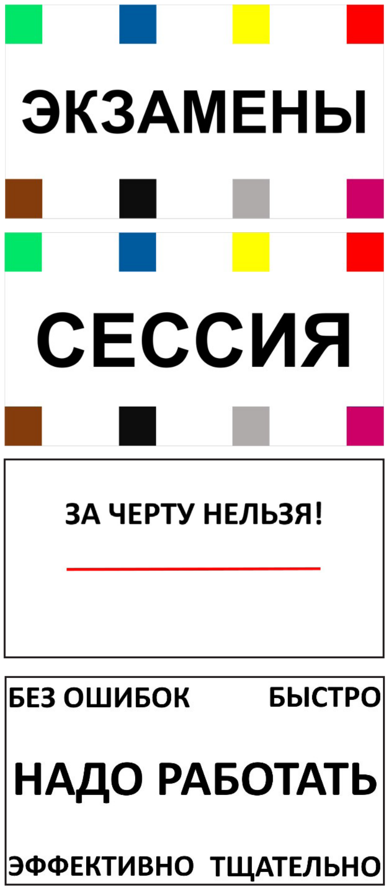

Figure 1. Examples of the used in the parallel recording cardio-oculometric indicators upon presentation of visual stimuli

a standard form of answers, which is used during the USE procedure.

samples of math examination tasks;

three runners at different distances from the finishing tape with the placed in the upper part of the stimulus wording WHERE ARE YOU?

located in the center of the stimulus, 110-point typed wording I AM A MAN with 90-point typed adjectives SUCCESSFUL, UNSUCCESSFUL, STRONG, WEAK in the corners;

red line with wording NOT TO CROSS THE LINE placed above the line.

located in the center of the stimulus, 110-point typed wording YOU NEED WORK with 90-point typed words WITHOUT MISTAKES, RAPIDLY, EFFICIENTLY, THOROUGHLY in the corners;

Examples of the mentioned stimuli are presented in Figure 1 herein.

When showing the above stimuli on the eyetracker screen (eyetracker) of the GP-3 type, the cardiograms of the examinees have been recorded using the Cardiocode computer-aided hemodynamic analyzer. Afterwards, using the algorithms embedded in the analyzers software, the Baevsky stress index (SI) values have been calculated for each examinee. Illustrations of this stage are shown in Figure 2 further herein.

The following psychological tests have been used as questionnaires in the study:

- Self-efficacy score by R. Schwarzer and M. Jerusalem (translated and adapted by V.G. Romek);
- the Keirsey Temperament Sorter (KTS);
- identification of subjective conditioning or readiness to stress tests;
- the TIPI-RU questionnaire
- self-estimate of susceptibility to stressful factors (M. Friedman, R.Rosenman);
- an analysis of life style (the Boston Stress Test);

In total, the study has covered 258 participants.

The statistical analysis of the obtained data has been performed using statistical package STADIA 8.0.

Results and discussion

The average SI values for various visual stimuli are presented in Table 1.

The first column of the present and all the following tables shows the numbers to indicate the visual stimuli as follows:

1 - toothy jaws of an attacking vampire bat;
2 - a pretty image of a giant panda;
3 - a huge spider devouring a wasp;
4 - a rattlesnake preparing to attack;
5 - a funny kitten playing around;
6 - 150-point typed word EXAMINATION;
7 - 190-point typed word SESSION;
8 - a standard form of answers, which is used during the USE procedure.

The static significance of differences in mean values was confirmed using the χ criterion (chi-square) that, as noted above, was evaluated using statistical package STADIA 8.0.

The obtained distributions differ from the Gauss-Laplace distribution. Therefore, in order to identify correlation relationships, we applied the Spearman and Kendall coefficients. Since the nature of the identified relationships for each of these coefficients and the factor structure revealed for each of them are similar, in the further analysis the data for the Spearman coefficient only are given because of its greater generality.

Table 2 shows the parameters of the factor structure after using the orthogonal rotation method (Varimax Rotation), with which we sought to minimize the number of variables with high loads on each factor.

Table 1
The main statistical parameters of the SI for various ego-states of respondents

Number of stimuli	Arithmetic mean	Standard deviation	Median
1	207,9	257	175,5
2	519,9	371,4	404
3	386,2	284,8	374,5
4	308,4	358,3	323,5
5	417,7	347,1	400
6	239,5	242,2	189
7	212,4	138	184
8	279,1	266,8	196

Table 2
Factor structure of the correlation relationships after the varimax rotation

Number of visual stimuli	Number of factor		
	1	2	3
1	0,7647	-0,2473	
2			0,8438
3			-0,526
4	0,519	-0,4196	
5			0,2821
6	0,9305		
7	0,7644		
8		-0,5418	

Table 3
Factor structure of the correlation relationships after the equimax rotation

Ego-states	Number of factor		
	1	2	3
1		-0,8557	
2			0,9165
3	0,4447		-0,7031
4	0,6404	-0,5715	
5			0,5107
6	0,8876		
7	0,8342	-0,4406	
8	0,3703	-0,7449	

In addition to the orthogonal rotation method (Varimax Rotation), we have also employed the methods as listed below:

- the quartimax rotation, with which we tried to minimize the number of factors, which are required for a meaningful interpretation of each of the variables involved;
- the equimax rotation (Equimax Rotation), which was used to simultaneously minimize the number of variables with large factor loads and the number of factors to interprete them;
- the oblique rotation (Oblique Rotation), with which we sought to minimize the number of factors without ensuring their full independence (orthogonality).

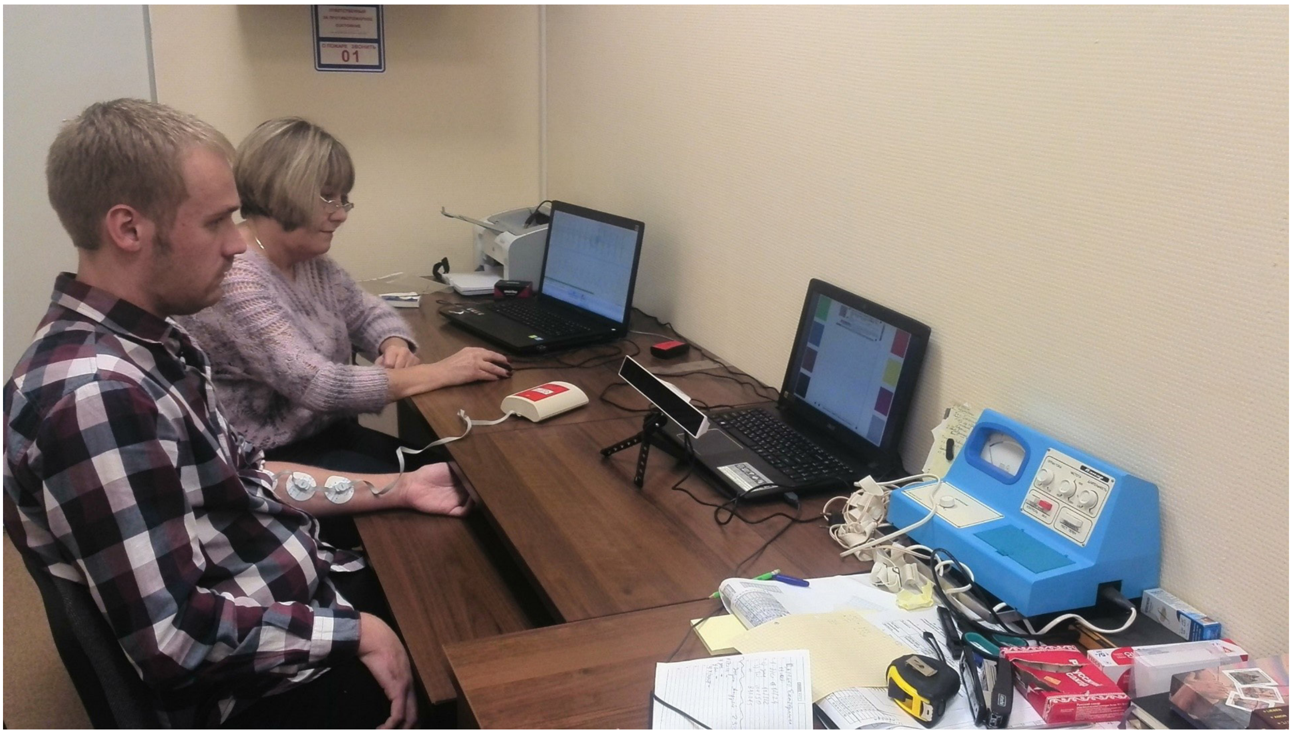

Figure 2. Demonstration of the parallel recording mode of respondent's cardiooculometric indicators of response to the USE form presentation.

Table 4.

Test scores	1	2	3
The USE results		0,367	
Stress tolerance (Boston test)	0,418	0,523	
Susceptibility to stress of type A (Friedman-Rosenman methodology)	0,462		
Subjective conditioning/readiness to USE			0,704
Extraversion (TIPI-RU questionnaire)	0,277		0,693
Friendliness(TIPI-RU questionnaire)	0,654		
Fairness(TIPI-RU questionnaire)		0,388	0,539
Emotional stability(TIPI-RU questionnaire)		0,402	0,528
Openness to experience (intelligence) (TIPI-RU questionnaire)	0,477		0,398
Self-efficacy		0,307	0,706
E score Extravertion (Keirsey questionnaire)	0,354		0,803
I score Introvertion (Keirsey questionnaire)	0,364	0,743	-0,396
S score Sensation(Keirsey questionnaire)		0,694	0,414
N score Intuition (Keirsey questionnaire)	0,734		
T score Thinking (Keirsey questionnaire)		0,727	
F score Feeling (Keirsey questionnaire)	0,756		0,328
J score Judging (Keirsey questionnaire)		0,623	0,307
P score Perceiving (Keirsey questionnaire)	0,686	0,401	

It has been found that the factor structure of the correlation relationships upon the oblique rotation (Oblique Rotation) exactly corresponds to the structure obtained after the varimax rotation (Varimax Rotation). When optimizing the factor structure of the revealed correlation relationships, we analyzed variants, which included from 3 (covered up to 80% of the dispersion and associated with larger losses of information) to 7 factors (covered over 90% of the dispersion and characterized by the presence of a significant

Table 5

variables	1	2	3	4
SI 1	0,462			-0,883
SI 2			0,338	-0,618
SI 3			0,782	
SI 4	0,894			-0,285
USE mark		0,887		

number of less informative relationships). With Kaiser normalization, optimal has been found the optimization of the factor structure in the revealed correlation relationships, which included 3 factors and covered over 81% of the dispersion. The data for the above optimization variant is given in Tables 2 and 3 herein.

As we can see from the data presented, the SI values obtained in response to the positive visual stimuli serve as a part of the number of a sort of some factors, and the SI values upon presentation of the negative visual stimuli such as word EXAMINATION, SESSION or a USE form are part of other factors. Moreover, this regularity and the above factor structure, as a whole, are preserved for all the rotation variants used. This, as well as the fact of statistically significant differences in average SI values, also demonstrates a substantial commonality of the positive stimuli, which significantly differs from that of the substantial nature identified for the SI values for the negative stimuli.

Statistically significant Spearman correlations are detected between the USE indicators and the values in accordance with such scores as stress tolerance (0.367), susceptibility to stress (-0.343), ability to come to an agreement (0.498) and fairness (0.519) according to the Big Five Personality Test (the TIPI-RU questionnaire), score I (0.356), S (0.347), T (0.478), P (0.342) from the Keirsey Temperament Sorter. The results of the factor analysis of the complete correlation matrix with the following varimax rotation are shown in Table 1herein.

As shown in Table 4, high results from the USE examination make a statistically significant contribution to the factor formed by high indicators of stress tolerance in respondents, their fairness and emotional stability. They are statistically significantly higher in the respondents having signs of temperaments of the ISTJ and ISTP type. As known, the success of these types of representatives in various activities is based on their intensive exercise training, participation in multiple repeatable tests of their ability to solve certain kinds of problems.

In addition to the mentioned psycho-diagnostic questionnaires for 48 examinees, who had favorable experience in successful completion of the USE, their response to stimuli used in the course of examinations in mathematics has been assessed. Sample assignments and forms to record the responses served as visual stimuli. Portable eyetracker (eyetracker) GP-3 has been employed to record the eye movement responses to the visual stimuli, the various capabilities of which in oculometric diagnostics and its beneficial application in combination with the Cardiocode PC-assisted hemodynamic analyzer are described in [5-7, 11, 12]. The time of each stimulus exposure and recording of the related cardiological data is 10 seconds. When working with each examinee, we have identified the stress index (SI) value in the organism's regulatory systems, as conditioned by each separate stimulus, and the heart rate (HR). When working with the stimuli, the time of the examinee's sight fixation at certain fragments of the visual stimulus has been recorded with the eyetreker, and its percentage (%) referred to the total stimulus exposure time has been computed.

Arithmetic average values of the SI parameters obtained by alternate demonstration of the Lüscher eight-color table, the assignments for mathematics from the USE demo version, the USE form and phrase "good mood" on the eyetracker screen were reported to be 513, 822, 611 and 537 units, respectively. Statistical significance of the differences between these values was confirmed by calculating a chi-square parameter, the values of which in all cases were not below 1894. The correlation relationships for the listed parameters were calculated according to Spearman, the factor structure of which is presented in Table 2 herein.

Table 5 shows the SI values as the variables of obtained by alternate demonstration of the Lüscher eight-color table (SI 1) on the eyetracker screen, for the assignment for mathematics from the USE demo version (SI 2), the USE form (SI 3) and phrase "good mood" (SI 4) and the final USE mark of the respondents. The indicated factor structure of the correlation relationships demonstrates that the nature of the response to stimuli associated with past examinations in the respondents does not depend on the degree of their success. It also follows from the table that the similar pattern of the response is observed when presenting the eight-color Lüscher table and phrase "good mood" on the eyetracker screen. Responding to the presentation of the assignments in mathematics from the USE demo version and an USE standard form is an independent factor.

During the post-test interviews more than a third of respondents have noted that a strong destabilizing factor is teachers and parents' statement that they doubt about the students' ability to successfully pass the upcoming USE examination. Very often such kind of doubts has been expressed by those respondents for whom it was typical to combine their intention to prepare their exam work free of errors and the desire to do any work as quickly as possible. Moreover, according to the respondents' statements, in many schools not enough attention is paid to preparing students for the procedure of passing such examinations. This fact is the most alarming thing for those types of the respondents, which are characterized by a combination of low self-esteem, lack of self-confidence and high self-control.

Conclusions

The obtained results have confirmed the validity of our assumption that PC-assisted cardiograph Cardiocode and modern portable GP-3 type eyetracker (eyetracker) allow assessing the psycho-physiological component of the students' conditioning/readiness for examination. During the confirmation of this hypothesis, we have also obtained statistically significant data that makes it possible to state that the mandatory part of preparation for examinations should be not only a subject-related training, but also a psychological conditioning of students targeted at improving their general stress tolerance and their emotional stability. An important part of such conditioning/preparation is also an educational activity, aimed at creating and strengthening the integrity of students, their fairness, increasing of their readiness to undertake the role of individuals solving vital problems. Versions of such conditioning/preparation, techniques and mechanisms included therein are described in detail in our papers [1, 2, 7, 14]. Within the framework of such conditioning activities, it is required to form skills of the control and regulation of their psychophysiological state in students. Particular attention should be paid to cultivation of capabilities of applying such skills in real daily practice in students.

The obtained experimental evidence has shown that transitions from a low level of psychophysiological conditioning of the students for their examinations to the respective high level thereof is really accompanied by significant changes in the organism performance, first of all, in the performance of the heart. Therefore, a reliable marker of such changes is the heart rate variability assessment using the Baevsky stress index (SI), as well as the oculometric peculiarities of response to the visual stimuli, which students associate with the upcoming examinations.

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

The authors read the ICMJE criteria for authorship and approved the final manuscript.

References

1. Abdurakhmanov RA, Agapov VS, NN Azarnov, et al. Modeling and optimization in human behavior. M, 2019.
2. Abdurakhmanov RA, Agapov VS, Adamov L.E., et al. Problems and achievements of modern stressology (monograph) / Ed. by A.S. Ognev. Moscow, 2020.
3. Zernov VA, et al. Application of computer cardiograph Cardiocode in engineering and social psychology. Higher education today. 2019:3:68-75.
4. Zernov V.A., et al. Cardiometric fingerprints of various human ego states. Cardiometry. 2019;15:38-42.
5. Lihacheva EV, Ognev AS. Optimization of procedure of assessing the subjective capacity of individuality. International Journal of Applied and Fundamental Research. 2015;8-2:375-7.
6. Lobanova EV, et al. Relation between personologic characteristics of students and their success in passing USE. In the collection: Psychology of health and disease: clinical and psychological approach. Proceedings of the IX All-Russian Conference with international participation. Edited by PV Tkachenko. 2019. P. 157-162.
7. Mishina MM, Ognev AS, Feoktistova SV. The values and purpose-in-life orientations of university students in russia and transdniestria. The European Proceedings of Social & Behavioural Sciences EpSBS. 2019. P. 413-422.
8. Ognev AS. Cardio-oculometric (cardio-oculographic) detection of functional states in a human individual. Cardiometry. 2019;14:104-5.
9. Ognev A.S., et al. Cardiometric detection of effects and patterns of emotional responses by a human individual to verbal, audial and visual stimuli. Cardiom. 2019;14:79-86.
10. Ognev AS, et al. Cardiometric taxonomy of stress-inducing potential in diverse domestic situations. Cardiometry. 2019;14:101-4.
11. Ognev AS, et al. Use of cardiometry and oculography in concealed information detection. Cardiometry. 2019;14:87-95.

12. Ognev AS, et al. Validity of cardiometric performance data: an integral part of complex assessment of training session effectiveness. Cardiometry. 2019;14:96-100.
13. Ognev AS, Likhacheva EV. Validity of eyetracking as a tool of psychodiagnostics. Advances in modern natural science. 2015(1-8):1311-4.
14. Ognev AS, Likhacheva EV, Sidorenko MG, Kazakov KA. Development of subjective potential of a person as a condition of increasing the competitiveness of students. Voronezh State Technical University Herald. 2013;9(5-2):181-3.
15. Workshop on the psychology of states / ed. by A.O. Prokhorov. St. Petersburg: Rech', 2004.