Dynamics of Heart Rate Parameters in Students with Various Personal Anxiety Levels during Computerized Testing

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Students with low level of initial (pre-test) personal anxiety demonstrated a high level of modulating effects on the heart rate in all basic frequency ranges (VLF, LF, and HF) resulting in a greater total power of heart rate variability spectrum compared to students with high personal anxiety. The peculiarities of dynamics of heart rate variability were revealed during a real learning task, which correlated with personal anxiety level. In comparison with highly anxious students, the low-anxious group demonstrated more pronounced drop in the power of all ranges of the heart rate variability spectrum during testing followed by restoration of these power indices to initial levels after completion of the test. In contrast, the drop of the total power of the heart rate variability spectrum and in the power of its individual components persisted in students with high anxiety level even after the end of the testing.

Key Words: *heart rate variability; anxiety; computerized testing*

Spectacular spread of computerized technologies in education explains the need and importance of the studies directed to physiological maintenance of computerized learning process in order to enhance its efficiency and to provide basic data about the effect of the computer-related work on the health of the schoolchildren and students. Working at computer is related to a number of health-affecting factors including those that could disturb the emotional sphere [5,7]. However, the computer-related health abnormalities were observed only in a part of examinees (25-70% according to various authors). Therefore, the study of individual peculiarities of physiological maintenance of the computer-based learning activity of the students with due account for their personal psychological features (first of all, anxiety and neurotism) is especially actual.

Our aim was to reveal peculiarities of ANS support of the learning intellectual activity in students with different levels of personal anxiety during computer-based testing of their knowledge.

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MATERIALS AND METHODS

The study has been carried out on men students (n=64) aging 18-21 years under informed consent. We examined the individual peculiarities of ANS maintenance of purposive activity modeled with a PC-based variant of a learning task. Before testing, general intelligence and personal anxiety of the students were assessed with H. Aizenk and C. D. Spielberger tests, respectively. Two physiological characteristics were recorded from the students sitting at PC monitor before (baseline 1), during (the test), and after termination of this test (baseline 2): ECG in standard lead III with a Polispektr 8E2 system (Neurosoft); BP with HR using an automatic tonometer. At each stage, the epoch was 5 min.

For each examinee, the percentage of correct responses to the learning task was determined for every student. ECG was analyzed with a Poli-Spektr-Ritm software (Neurosoft). The following stochastic parameters and indices of spectral analysis of the heart rate were selected on the basis International Standards [6] and published reports [1,3,4]: RRNN (msec), mean *R-R* normal-to-normal interval; CV, coefficient of variation of the *R-R* intervals; TP (msec^2/Hz), total

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spectral power in 0.003-0.400 Hz frequency band; HF (msec^2/Hz), high frequency wave power in 0.15-0.40 Hz; LF (msec^2/Hz), low frequency wave power in 0.04-0.15 Hz; VLF (msec^2/Hz), very low frequency wave power in 0.003-0.040 Hz; and LF/HF (rel. units), autonomic balance index (ABI).

To assess the changes of ANS parameters for each student, the differences δ were calculated for the above indices at each stage of the examination.

The data were analyzed statistically with correlation and dispersion analysis under Statistica 6.0 software. For normally distributed indices, the data were presented as *m*±SEM. Since HRV spectral parameters were not distributed normally, the non-parametrical statistics was employed yielding the median and the interquartile range between the first and the third quartiles. Significance was assessed by Mann–Whitney and Wilcoxon tests. Spearman's correlation analysis was also employed.

RESULTS

The baseline HRV parameters and their changes during testing were related to personal anxiety of the examined students. Anxiety negatively correlated with the initial values (baseline 1) of the following HRV indices: CV (r=-0.398, p=0.002), TP (r=-0.326, p=0.011), VLF (r=-0.263, p=0.042), LF (r=-0.311, p=0.016), and HF (r=-0.332, p=0.009). Overall, CV, RRNN, TP, and band powers in the selected HRV spectrum parts

TABLE 1. HRV Parameters in Students with Low (Group 1), Medium (Group 2), and High (Group 3) Personal Anxiety at Different Stages of Computerized Testing (Median and Interquartile Range from 25 to 75%)

Index	Stage	Group 1	Group 2	Group 3	p (1-2)	p (1-3)
TP, msec^2/Hz	Baseline 1	7120 (4972; 13,856)	5007 (3233; 9264)	4355 (3226; 5742)	0.049	0.011
	Test	4257 (2863; 6185)	3732 (3148; 4993)	3342 (2229; 4841)	-	-
	Baseline 2	5937 (3770; 9604)	4129 (2962; 8715)	3904 (2400; 6581)	-	0.048
	p (b1-t)	<0.001	0.003	0.019		
	p (t-b2)	0.001	-	-		
VLF, msec^2/Hz	Baseline 1	2803 (1922; 4475)	2185 (1173; 5390)	1634 (831; 2914)	-	0.012
	Test	1186 (912; 1629)	1629 (1022; 1960)	1196 (744; 1574)	-	-
	Baseline 2	2337 (1312; 2868)	1692 (1022; 2473)	1145 (740; 2440)	-	-
	p (b1-t)	<0.001	0.009	0.008		
	p (t-b2)	<0.001	-	-		
LF, msec^2/Hz	Baseline 1	2408 (1694; 3394)	2198 (1330; 2534)	1586 (935; 2434)	-	0.015
	Test	1735 (1243; 2243)	1419 (1096; 2209)	1801 (788; 2679)	-	-
	Baseline 2	2148 (1808; 3358)	2324 (1510; 3672)	2116 (1245; 2870)	-	-
	p (b1-t)	0.008	0.050	-		
	p (t-b2)	0.01	0.009	-		
HF, msec^2/Hz	Baseline 1	1687 (730; 4537)	1151 (326; 1660)	839 (431; 1973)	0.039	0.029
	Test	828 (443; 1511)	439 (256; 1079)	491 (220; 1187)	-	-
	Baseline 2	1305 (762; 3742)	645 (329; 1380)	602 (381; 1252)	-	-
	p (b1-t)	<0.001	<0.004	-		
	p (t-b2)	0.005	-	-		
LF/HF	Baseline 1	1.31 (0.75; 1.92)	2.77 (1.14; 4.46)	2.05 (1.02; 3.98)	0.044	0.048
	Test	2.35 (1.09; 4.0)	3.89 (1.18; 4.48)	3.37 (1.71; 4.87)	-	-
	Baseline 2	1.88 (0.93; 2.43)	2.97 (1.57; 4.69)	2.5 (1.79; 4.31)	-	0.047
	p (b1-t)	0.004	-	-		
	p (t-b2)	-	-	-		

Note. Significance of differences between groups 1 and 2 — p (1-2), groups 1 and 3 — p (1-3), baseline 1 and test — p (b1-t), test and baseline 2 — p (t-b2).

decreased during testing. The degree of these decrements (δ) was individual, and it negatively correlated with the personal anxiety: δTP, r=-0.326, p=0.011; δLF, r=-0.389, p=0.002; δHF, r=-0.409, p=0.001; δCV, r=-0.330, p=0.010. During testing, there was no linear correlation between personal anxiety, on the one hand, and the hemodynamic parameters or HRV indices, on the other. After completion of the test (baseline 2), the level of personal anxiety positively correlated with LF/HF ratio (r=0.272, p=0.038) and negatively with HF (r=0.283, p=0.030). At this, the examinees with low personal anxiety demonstrated significantly greater increment in HF (r=0.327, p=0.011).

For a detailed study of the changes in HRV parameters and hemodynamic indices before, during, and after purposive activity in persons with different anxiety, all the students were divided into 3 groups with low (group 1, n=23), medium (group 2, n=20), and high (group 3, n=21) personal anxiety. These groups significantly differed by anxiety score (33.4±0.8, 41.3±0.3, and 49.1±0.9 in groups 1, 2, and 3, respectively) and neurotism score (5.5±0.5, 8.5±0.9, and 12.5±0.7). The results of the learning task did not significantly differ in these groups, although students of the medium-anxiety group 2 demonstrated a trend to greater percentage of correct answers with the following scores: 50.9±2.9, 59.8±3.8, and 55.7±4.5% in groups 1, 2 and 3, respectively.

Initially, the students with low personal anxiety demonstrated significantly greater HRV indices of TP, VLF, LF, HF (Table 1) and CV (Fig. 1, p=0.003) than those with high personal anxiety. In group 2, the HRV indices were intermediate between the corresponding values in groups 1 and 3. It is noteworthy that the persons with high anxiety are characterized by selective inhibition of respiratory arrhythmia and Traube–Hering–Mayer waves (about 0.1 Hz) which are assumed to be related to domination of the passive defensive reflex within the structure of cognitive activity [2]. Despite diverse views on the mechanisms underlying different bands of HRV spectrum, it has been established that LF oscillations are associated with activity in the postganglionic sympathetic fibers, so their spectral power characterizes the sympathetic influences to the cardiac rhythm. In contrast, the oscillations in HF-band of respiratory origin are considered as a measure of cardiotropic parasympathetic influences, while the ratio LF/HF (ABI) is employed to assess the balance between both branches of ANS [1,3,4,6]. Our data showed that the initial state of the students with low personal anxiety was characterized by greater sympathetic and parasympathetic modulating influences on the heart rate. Interpretation of the differences in VLF values observed in the students with various personal anxiety levels is problematic. The origin and genesis of VLF-oscillation are little known [3,4], so at this stage, it seems reasonable just to report the revealed differences.

At the initial state, the students with low personal anxiety demonstrated ABI of about 1 attesting to somewhat "balanced" influences of sympathetic and parasympathetic branches of ANS on the cardiovascu-

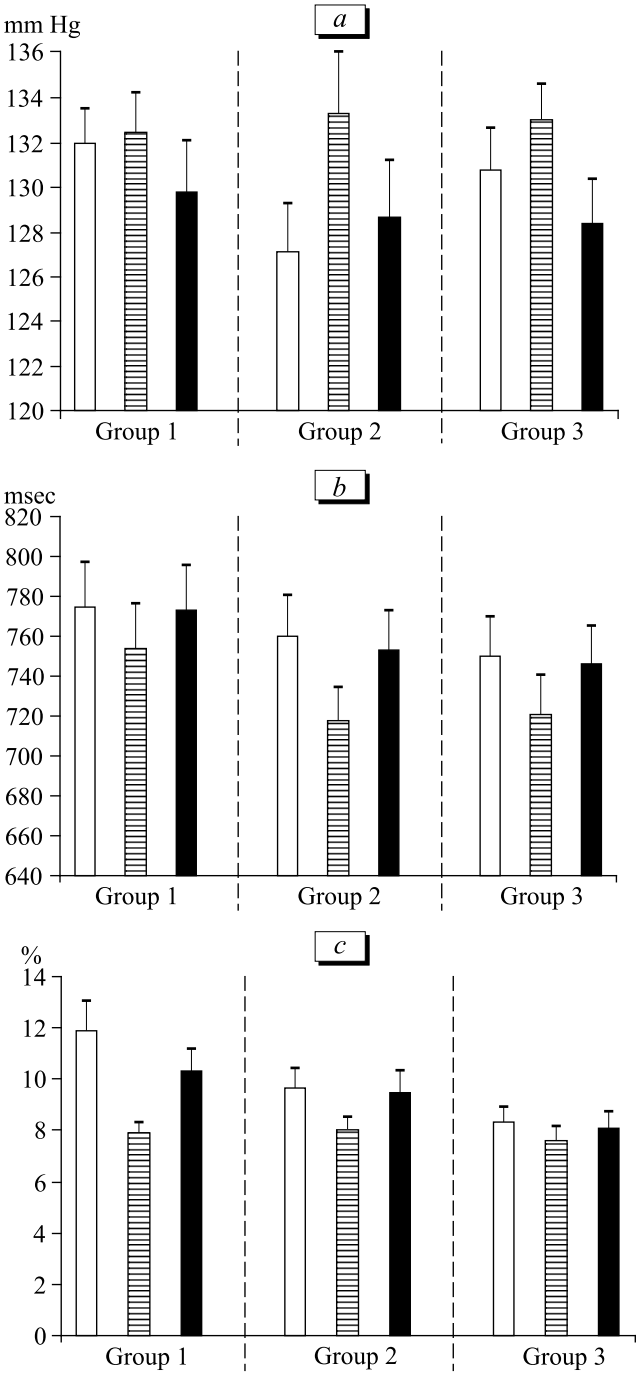

Fig. 1. Systolic BP (*a*), RRNN (*b*), and CV (*c*) at various stages of purposive activity in students with low (group 1), medium (group 2), and high (group 3) personal anxiety (m±SEM). Open, dashed, and dark bars show the data before, during, and after testing, respectively.

lar functions. By contrast, significantly greater values of ABI indicating prevalence of sympathetic influences on the heart were observed in students with medium and high anxiety levels.

During testing, the students with low anxiety demonstrated significant decrease of spectral power in all frequency ranges (Table 1), RRNN (p=0.003), and CV (p<0.001, Fig. 1), as well as significant increase of ABI (p=0.004). After termination of the test, the spectral power in all frequency ranges significantly increased to the levels that did not significantly differ from the baseline values. In addition, RRNN (p=0.007) and CV (p=0.003) increased significantly, while ABI decreased to the baseline value.

When tested, the students with medium level of personal anxiety were characterized by significant decreased spectral power in all frequency bands (p=0.001), RRNN (p=0.001), and CV (p=0.016); in addition, their systolic BP was elevated (p=0.021). After termination of the test, systolic pressure dropped significantly (p=0.08), while RRNN and LF increased (p<0.001). There was no significant increase in CV, while TP, VLF, and HF remained decreased.

When tested, the students with high level of personal anxiety had lower TP, VLF, and RRNN in comparison with the corresponding baseline 1 values (p<0.001). After testing, systolic BP decreased (p=0.020), while RRNN increased (p=0.002). In this group, TP, VLF, HF, and CV remained low, while ABI was maintained at a high level, which was significantly greater than that in the low anxiety group.

Our study revealed an apparently paradoxical phenomenon: more pronounced decrease of spectral power in major frequency bands and, respectively, a greater drop in total spectral power during testing in students with low anxiety level in comparison with high anxiety group. Two features are principally important for explaining this difference. The first is high values of spectral power in all frequency bands in students with low personal anxiety and the second is the transient character of the observed drops in spectral power indices, which returned to the initial values after termination of the test. Taking into consideration that decrease in TP is generally considered as indication of mobilization of the functional reserves [1], it can be hypothesized that moderation of initially high HRV spectral power in all frequency bands during testing reflects mobilization of vegetative functions directed to support the purposive activity in students with low personal anxiety.

In contrast, the decreased parameters of total TP, VLF, and HF observed in students with medium and especially high personal anxiety during testing did not restore after termination of the test attesting to persistent and stagnant character of the changes in HRV parameters in anxious persons.

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