**Psychophysiological and neurophysiological characteristics of enforced distance learning within the biochemistry course**

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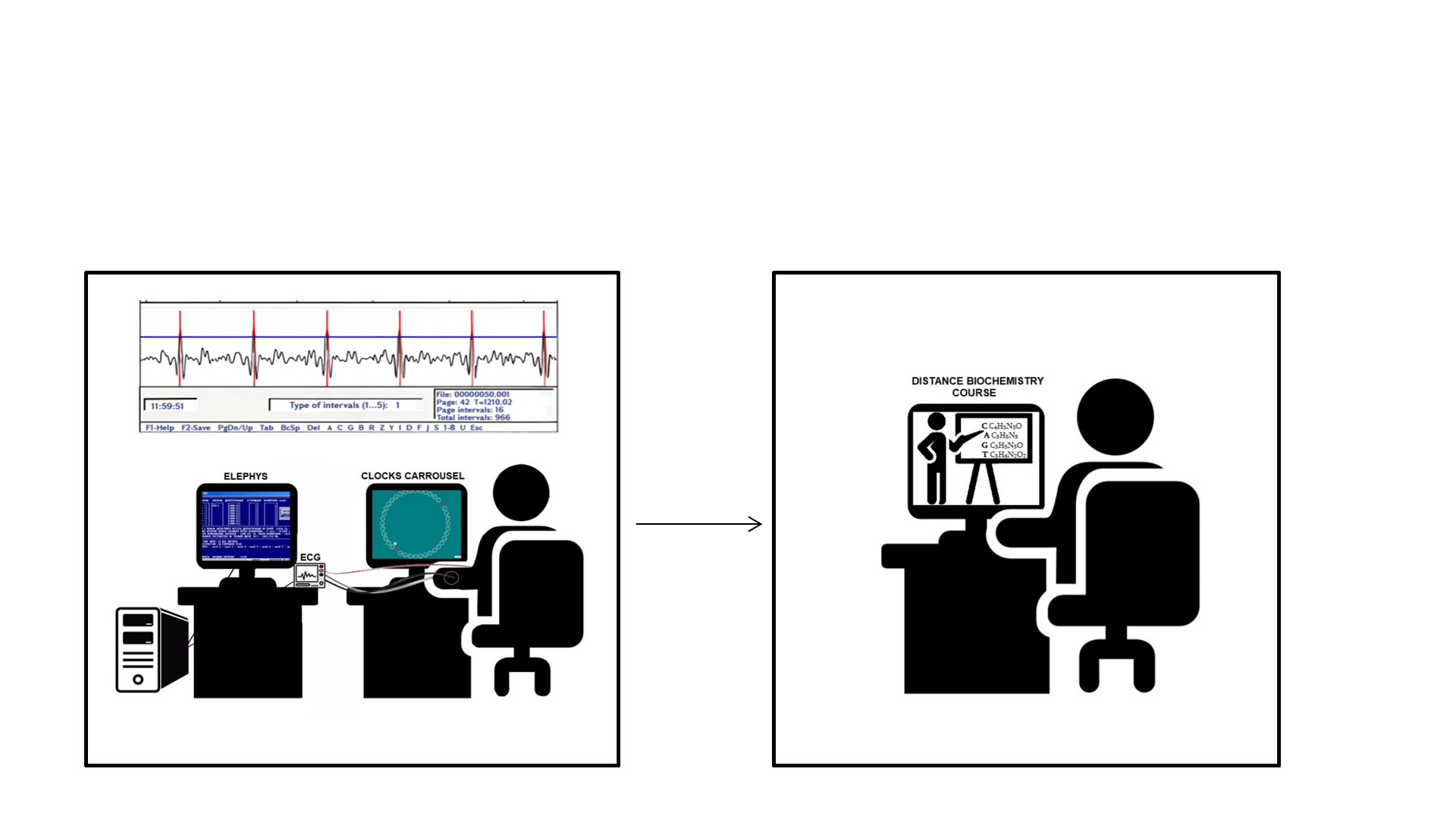
**ABSTRACT**

The main goal of the presented work is to evaluate the psychophysiological and neurophysiological processes of students of enforced distance learning within the biochemistry course of different (80 and 60 minutes) duration. The research was conducted due to the outbreak of COVID-19 during a period of sudden transition from a traditional format to the distance-learning one. After the 80-minute lesson, in contrast to the 60-minute lesson, 19-21-year-old students showed a decrease in attention concentration, cognitive processes, and mental performance. Enforced distance learning lasting 80 minutes was accompanied not only by cognitive load but also by stress-induced changes in learners. Physiological changes caused by mental load were assessed by recording the electrocardiogram (ECG) using the biofeedback method (mathematical analysis of heart rate variability). The processes of activation of the sympathetic mechanisms of the central nervous system and the changes in the heart rhythm, as well as the heart rate variability balance, caused by them, indicated the tension in the students’ bodies.

The stability of psychophysiological and neurophysiological processes in emergency situations during an 80-minute biochemistry class requires a high level of stress from students.

**Keywords:** Distant learning, attention, Cognitive load, Biofeedback method.

**Graphical Abstract**



**Graphical Abstract text**

Assessment of the psychophysiological and neurophysiological processes of students of enforced distance learning within the biochemistry course of different (80 and 60 minutes) duration.

**1 | INTRODUCTION**

**1.1 COVID-19 Pandemic Outbreak vs. Education**

Technocratic education is accompanied by a sharp increase in informational, emotional and psycho-emotional stresses when, in addition to technological congestions, natural disasters and epidemics also generate an adverse impact on the quality and content of education.

Since the moment of the COVID-19 pandemic, the process of transition from the traditional educational format to enforced distance learning, as well as the competent arrangements on virtual courses, have become the highest priority for all educational institutions.

Teaching, lecturing and research staff, scholars and students, communities, public societies and all of humanity have faced stress, fear, anxiety, panic, unrest and depression (Rodríguez-Hidalgo et al., 2020; Kim and Asbury, 2020; Racine et al., 2021; Talidong and Toquero, 2020). The coronavirus pandemic had a unique feature, i.e. forced isolation, which was precisely the component causing the depression (Brooks et al., 2020; Liozidou et al., 2023), the growth of inactivity, weakened immunity and chronic fatigue syndrome persisting in the human body for a long time, the latter also having a respective impact during the post-COVID phases.

The quality of education has also undergone significant changes worldwide: the immediate transition from traditional to distance learning caused a decrease in academic performance (Aucejo et al., 2020; Ahmady et al., 2020; Yamin, 2020). In order to ensure effective distance learning, any research has become an absolute and complete necessity for educational and scientific institutions (Affouneh et al., 2020; Carey, 2020; Favale et al., 2020). According to the research study conducted by the International Association of Universities, the impact of distance learning on the higher education framework during COVID-19 is as follows herein: termination of university activities - 59%, impossibility to complete the scientific research on time - 52%, setback of cooperation and interaction - 64%, decrease in academic mobility - 89% (Marinoni et al., 2020); the research on the psychological, psychological-pedagogical aspects of students in a virtual environment reflects the gender, age, cognitive, and social characteristics of the mentioned aspects.

The evaluation of emotional, psycho-emotional, (and, mainly, the “academic emotions”) neurophysiological criteria of students is also considered to be of key importance (Pecrun et al., 2017; Levenson et al., 2017; Panadero, 2017; Loderer et al., 2020). Hence, the accurate, precise and competent implementation of distant learning in an emergency situation requires the development of a number of tools and mechanisms (Ahmady et al., 2020; Yamin, 2020; Rieley J. B., 2020.; Tyler et al., 2021), in particular, the volume of the student’s academic load, as well as the adequately set duration of the lesson, the latter allowing the student to adapt to professional activities to the most possible extent.

**1.1.2 Educational Challenges in Armenia**

Since 2020, the COVID-19 pandemic in Armenia has created great challenges for the education system. Universities, schools and kindergartens were shut down, as a result of which more than 30 thousand Armenian students and children were deprived of the right to education. According to the data of the 2021 survey, 39% of people associated with distance education within the Armenian educational framework have mentioned as the main disadvantage of distance education the inability to concentrate, 27% - the formal apprenticeship of scholars or students during the studies without being involved in the educational process. 22% of respondents believe that under the conditions of distance education, each scholar or student is granted less time. Another 22% of respondents mentioned that a disadvantage of distance education is the additional difficulties in developing practical skills for students (Caucasus Research Resource Center (CRRC) - Armenia, 2021).

At the moment of the pandemic, no duration time for distance learning classes has been set in educational institutions of our republic (Armenia), and the latter in such institutions were conducted throughout classes set for traditional education. In contrast, the duration of classes for both natural science and humanitarian streams was set at 80 minutes. In general, they were accompanied by various complications, especially for students of the natural sciences.

Before conducting this study, we implemented a survey conducted among students of the Faculty of Biology, Chemistry and Geography of the Armenian State Pedagogical University (ASPU) named after Kh. Abovyan. The survey showed that during enforced distance learning (COVID-19) (the first and second semesters of 2021), most of the students failed to maintain concentration at the required level until the very end of the lesson (80 minutes). They showed expressive fatigue with an absolute lack of motivation to study. It became clear from the surveys that determining the optimal ranges of class time in accordance with the complexity of the course was a particularly urgent task, especially for students of the natural sciences. Taking into account the opinion of the students, among the natural sciences courses, we chose the biochemistry course, which, among other biological sciences, is distinguished by its complexity.

**1.2 Key aspects of the study**

The formation of virtual classrooms requires from students a higher level of mental efforts in the meaning of the assimilation of large volumes of information and material, qualified skills of practical independent work, self-organization, independent work planning, the maximum level of attention expected from students, while the mental stress can disrupt the normal learning process (Muilenburg & Berge, 2005; Sit et al., 2005; Benjamin, 1994; Cook et al., 2008; Pei & Wu 2019). The latter can lead to disruption of the normal functioning of the cardiovascular, nervous and other systems and negatively affect academic performance. But this issue becomes even more problematic under the bound and restrained conditions of education when there is a lack of a full-fledged and full-blooded living environment (forced isolation, fear, unrest, anxiety, expectations, uncertainty), decreasing the key essential indicators of the quality of student’s life (Benjamin, 1994; Cook et al., 2008; Pei & Wu, 2019)

It is noteworthy that the effectiveness of teaching in such conditions is characterized not only by the level of socio-psychological well-being of students but also by appropriate physiological attitudes, in particular psychophysiological and neurophysiological features.

The study examined the psychophysiological and neurophysiological features of distant learning arrangements in emergency situations. The functional activity of brain structures determining the coordination of processes that require prolonged concentration during training was evaluated, i.e. the attention, mental performance, information and material assimilation and the presetting the control over the mentioned were assessed as well. Through the application of a psychophysiological test developed by analogy with the d2 test (Brikenkamp, 2012; Tumanian et al., 2021), a comprehensive study of the attention process was conducted, considering the qualitative and quantitative components characterizing volitional attention.

Applying the biofeedback method (ECG, HRV MA), which is used to assess the stress process that occurs in the body of students as a result of cognitive overload, the externally invisible vegetative changes in students that constantly accompany mental processes were studied. These are effective methods for measuring physiological changes (vegetative indicators) (Kim & Jo, 2019; Haapalainen et al., 2010; Cranford et al., 2014; Ababkova & Leontyeva 2017,2018; Kovalevskaya 2015)

**The purpose of the research** was to study the attention, mental performance and neurovegetative processes of biology stream students learning remotely under the conditions of the Coronavirus pandemic during the biochemistry course of 80 and 60 minutes duration.

**1.3 Research Issues**

**To achieve the objectives of the study, we raised the following questions**

1) What is the extent of effectiveness of 60-minute and 80-minute enforced distance learning for natural science students, and how the duration of learning in the absence of favourable living conditions can affect the psychophysiological and neurophysiological processes of natural science students,

and, in particular

2) What is the attention span and sustainability, as well as the mental performance of biology students studying under enforced distant learning within the 60-minute and 80-minute biochemistry course,

3) What is the functional activity of the heart rate and the integrative brain structures involved in its regulation in students under enforced distant learning within the long-term and short-term course of biochemistry.

**2 | MATERIAL AND METHODS**

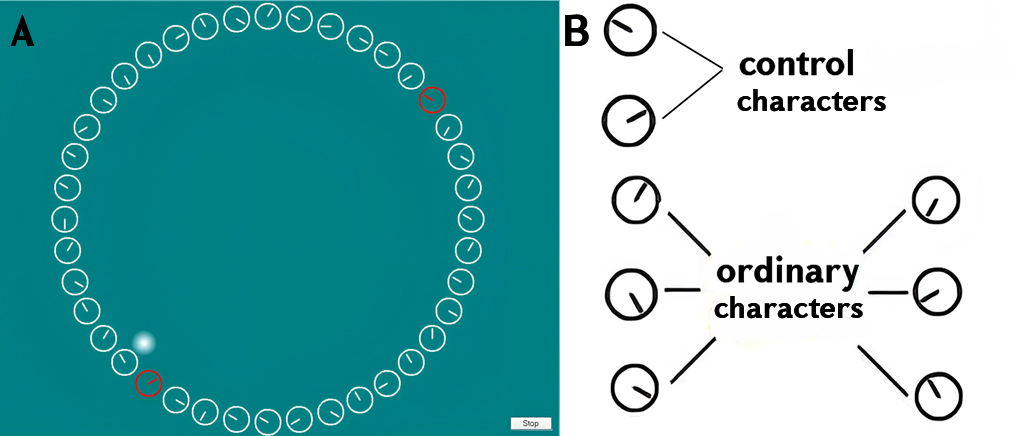
**2.1 Participants**

The research was conducted among students aged 19-21 (n=110) of the Biology Department of the Faculty of Biology, Chemistry and Geography of ASPU, studying full-time, in the first half of the day (from 9:30 to 16:00) in the context of the COVID-19 pandemic (1st and 2nd semesters of 2021), during the transition from the traditional to the distance learning format. Participation in the study was arranged on a voluntary basis. The students under research and examination were familiarized in detail with the conditions of the experiment online, as well as were explained the importance of all the components of the experiment, and a respective test provided under the scheme was conducted with detailed information about the order and procedure for completing the appropriate tasks. Having received comprehensive information about the prerequisites for the correct implementation of all the components of the experiment, the students under the test expressed a willingness to join the remote classes provided for in the schedule of classes at the Laboratory of Experimental Human Physiology of the ASPU. The distant classes were conducted using the ASPU Google Classroom (Google for Education tool) implemented in ASPU, using the ASPU Google Meet application. The duration of the distance lesson in the same group of persons under study was set at 80 and 60 minutes.

**2.2 Methods and Approach**

**Psychophysiological research.** Within the purpose of the comprehensive study of the attention process, in particular, the study of volitional attention, a specially developed computer-based psychophysiological “Clocks Carrousel” (Fig.1) test has a wide range of software options was applied, the latter being developed by analogy with the d2 test (Brickenkamp, 2012; Tumanian et al., 2021)

Within the framework of the test, the person under study was given the following task: constantly and as quickly as possible rotating the on-screen spherical cursor in a circle to try to accurately indicate the “clocks” (“control clock”) showing a particular “time” (22:00; 14:00). The prototyping instructions explained, that the circles illustrate “clocks”, and the lines inside are small hands of the clock. Assessments of attention and mental performance were carried out by the appropriate program/software, which took into account the speed of the test and the number of mistakes made (incorrect notes, omissions).

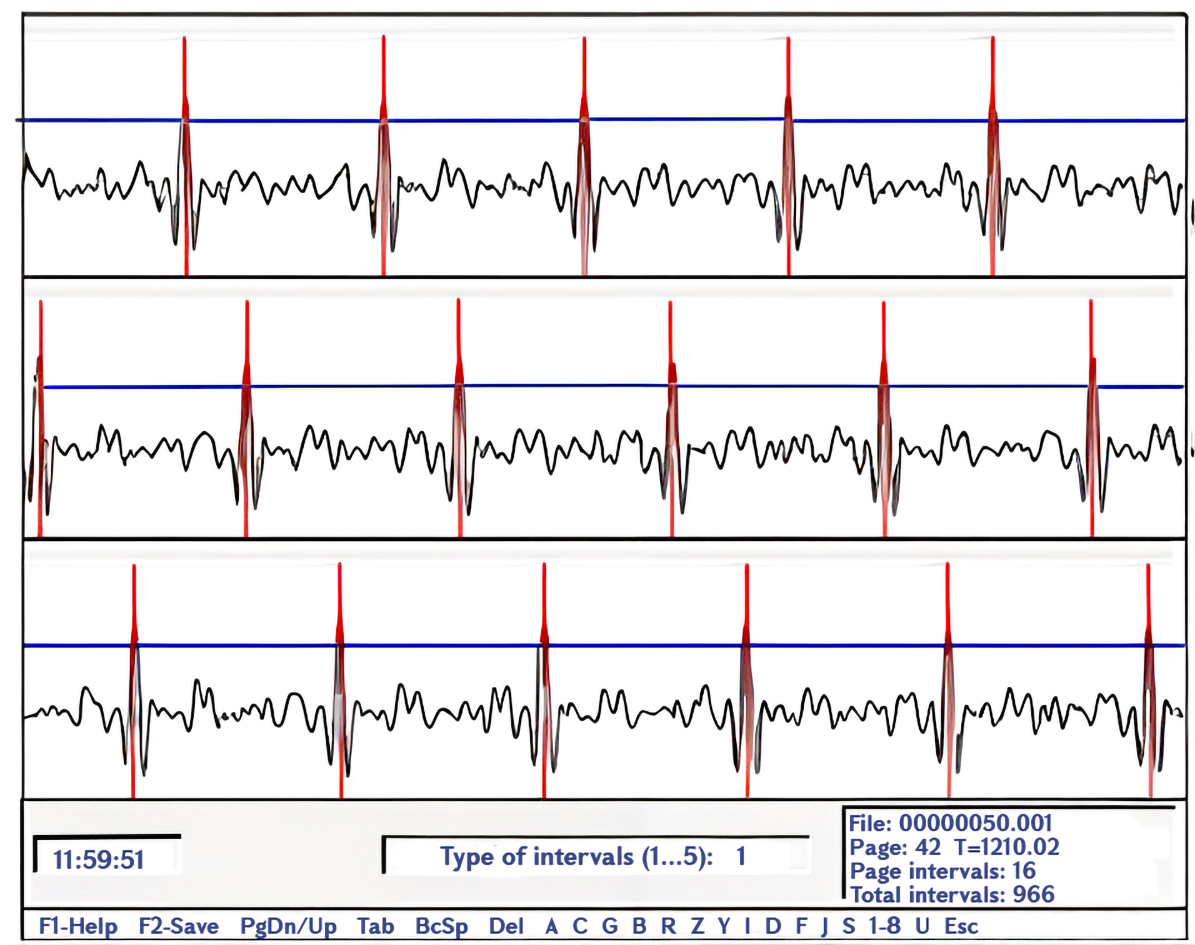
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**Fig. 1 A** **The computer-displayed image of the working field under the Vigilance Research psychophysiologically correctional proof test for assessing the attention and mental performance on the computer display screen. B Control and ordinary characters of the psychophysiological “Clock Carrousel” test.**

**Among the functional indicators of attention, the following were evaluated:** **Ac%** (accuracy of performance), total number of errors **TNE%**, number of incorrectly omitted **IMS%** and incorrectly pressed **ICS%** characters, **M\_Cap** (c.u.) (Mental capacity) and **CI%** (the indicator of concentration). The indicator of attention concentration is determined by the difference in the number of correctly and incorrectly pressed characters (CCS-IC), where CCS is the actual number of correct answers;

**Among the time-based indicators of attention, the following were evaluated:** **M\_PT (sec.)** (Mean time of 1 figure processing), the average processing time of 1 character in the correctional proof-test; **SD\_PT (sec.)** (SD of the mean time of 1 figure processing) as it’s standard deviation; **RDCF\_dmT (sec.)** (Rightly deleted control figures decision-making (dm) times), **WDOF\_dmT(sec.)** (Wrongly deleted ordinary figure decision-making (dm) times) –respectively when taking the decision on fixing correctly pressed control characters and incorrectly pressed ordinary characters, **RDCF\_aeT(sec.)** (Rightly deleted control figures after effect (ae) times), **WDOF\_aeT(sec.) (**Wrongly deleted ordinary figure after effect (ae) times), the analysis of correctly pressed control characters and incorrectly pressed ordinary characters during the post-action, being the time of “recovery” and readiness to respond to the subsequent action.

**Neurophysiological studies** were conducted using the mathematical analysis of heart rate variability using electrocardiogram (HRV MA) tracing (biofeedback method). HRV is judged by the duration of the R-R intervals, which is determined by the greater amplitude and prominence of the R wave on the electrocardiogram (Fig.2). For this purpose, the time series (intervalograms) of the intervals of the R-R waves of the ECG were subjected to mathematical analysis.



**Fig. 2 Screenshot of the working window of the “ELEPHYS” program**.

In interactive mode, the process of recognizing the R waves of the ECG and measuring the R-R time intervals.

The vertical lines indicate the R-R intervals, which are later subjected to mathematical analysis.

The electrocardiogram (ECG) was recorded for 20 minutes in a sedentary position, with the first-turn manifestation (left hand - right hand).ECG recording and mathematical analysis of heart rate variability indicators using the “ELEPHYS” hardware-software complex (Gevorgyan 1995) was performed during the execution of the “Clocks Carousel” test.

Among the indicators obtained using a histogram of HRV analysis or the method of variational heart rate monitoring, the following were evaluated:

**SI - stress index**, which is calculated by the formula SI = Amo/(2\*MxDMn\*Mo)

**АМо (mode amplitude)-**is a number of intervals corresponding to mode value in % to sample size.

**MxDMn (Variation range)** - shows the degree of interval variativity in a given dynamic series. It is calculated from the difference of maximum (Mx) and minimum (Mn) intervals and, therefore, can be distorted by arrhythmias or artifacts.

**Мо (mоde)** - Mode is the most common interval value in a given dynamic series.

The relative values ​​of the three spectral components of the frequency range: VLF, LF, HF were estimated from the indicators obtained by the spectral method of heart rate variability analysis in percentage terms.

**HF power %** Relative power of the high-frequency band (period 3-7 s, power in the range 0.15-0.4 Hz)

**LF power %** Relative power of the low-frequency band (period 7-30 s, power in the range 0.04-0.15 Hz)

**VLF power %** Absolute power of the very-low-frequency band (period 30 s and more, wave power in the range 0.0033–0.04 Hz)

**HRV time domain indicators**

**SDNN** (Standard Deviation of Normal-to-Normal interbeat intervals)

**RMSSD -** Root Mean Square of Successive Differences

**2.3 The Course of Study**

The series of tests were held in the following stages:

* Assessment of students’ attention and mental performance with simultaneous electrocardiogram tracing for 80 minutes before and after the biochemistry session;
* Assessment of students’ attention and mental performance with simultaneous electrocardiogram tracing for 60 minutes before and after the biochemistry session;

It should be noted that the duration of the lesson under normal conditions, as per-set in the ASPU, is 80 minutes. Therefore, we have received prior consent from the lecturers for those students undergoing this testing before and after a 60-minute biochemistry lesson.

The entire testing process was carried out in accordance with the Helsinki Declaration on Ethical Principles for Medical Research Involving Human Subjects (the Ethics Committee of the Yerevan State Medical University after M. Heratsi (N12-1/22)).

**2.4 Data analysis**

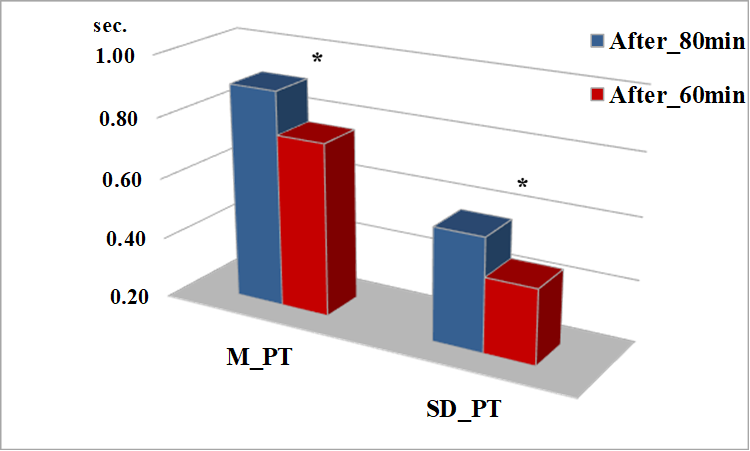
Data are presented as mean ± standard deviation (M±SD). Statistical analysis of two dependent groups was performed. The normality of the data distribution was determined using the Shapiro-Wilk and Kolmagorov-Smirnov criterion, and the homogeneity of variance was determined using the Levene test. In the case of normal distribution and homogeneity of variance, one-way analysis of variance (ANOVA) was used for intergroup comparison. To detect differences in the mean values of the study groups, a posteriori analysis was performed using the Bonferroni criterion. In the case of a Gaussian, parametric distribution of data, the reliability between groups was determined using the Student's t-test (t-test for paired samples), and in the case of a non-normal distribution, using the Mann–Whitney U-test (Mann–Whitney U test). Data were considered significant at the p<0.05 level. Statistical analysis was performed using SPSS software (version 26.0).

**3 | RESULTS**

**3.1 Comparative changes in concentration time after 80- and 60-minute duration distant learning sessions**

The time-based attention indicators were evaluated as follows below:

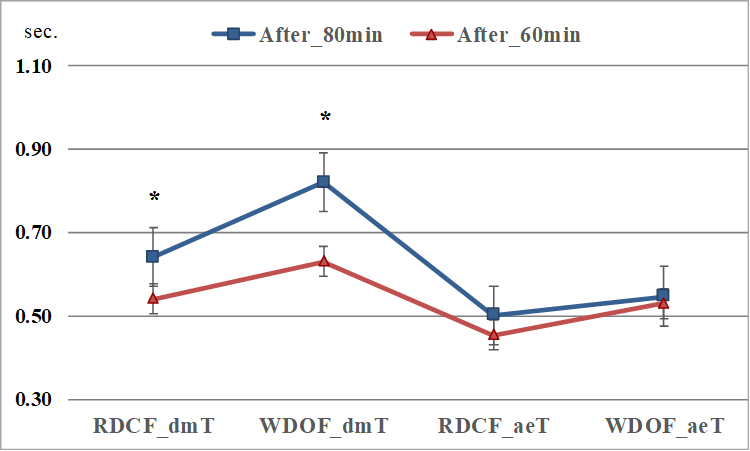
**M\_PT (sec.),** the average processing time of a character in the correctional proof test; **SD\_PT** **(sec.),** the standard deviation of the latter; **RDCF\_dmT (sec.),** the correctly pressed control character, **WDOF\_dmT (sec.),** when taking the decision on fixing incorrectly pressed ordinary characters; **RDCF\_aeT (sec.),** the correctly pressed control character and **WDOF\_aeT (sec.)** the incorrectly pressed ordinary characters during the post-action, being the time of “recovery” and readiness to respond to the subsequent action.

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**Fig.3 A diagram of the dynamics of time indicators at two post-lesson stages**

M-PT (sec.), the average processing time of 1 character; SD-PT (sec.), the standard deviation. The ordinate axis shows the M-PT and SD-PT (sec.) values. The M-PT and SD-PT indicators in the post-class stages are depicted on the abscissa axis. Where: the \* is the reliability at the level of p<0.05.

At two post-session stages (after 80- and 60-minute duration lessons), there are specific changes in cognitive processes and volitional attention, with a tendency to decrease their effectiveness. The analysis of time indicators shows the registered differences between 80- and 60-minute sessions, in particular, the average information processing time, **M-PT** (sec.) and the standard deviation **SD-PT** (sec.), having increased by 18.32% (p<0.05) and 28.2% (p<0.05) accordingly after the 80-minute session (Fig. 3).

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**Fig. 4** **The linear diagram of the dynamics of time-based indicators at two of the post-session stages.**

The acronyms are RDCF\_dmT (sec.) WDOF\_dmT(sec.) respectively - when taking the decision on fixing correctly pressed reference characters and incorrectly pressed ordinary characters RDCF\_aeT(sec.), WDOF\_aeT(sec**.)** is the analysis of correctly pressed control characters and incorrectly pressed ordinary characters during the post-action phase. The ordinate axis shows the RDCF\_dmT, WDOF\_dmT, RDCF\_aeT, and WDOF\_aeT values. The RDCF\_dmT, RDCF\_aeT, WDOF\_dmT, and WDOF\_aeT indicators in the post-class stages of the research are depicted on the abscissa axis. Where: the \* is the reliability at the level of p<0.05.

The comparative analysis for time-based indicators (**RDCF\_dmT** – (for correctly pressed control characters and **WDOF\_dmT**(sec.) (for making decisions on wrongly pressed control characters) after 80- and 60-minute duration distant learning sessions is presented with characteristic changes. After 80 minutes of distance learning, they show higher values of 19.2% (p<0.05) and 30.2% (p<0.05) respectively (Fig. 4).

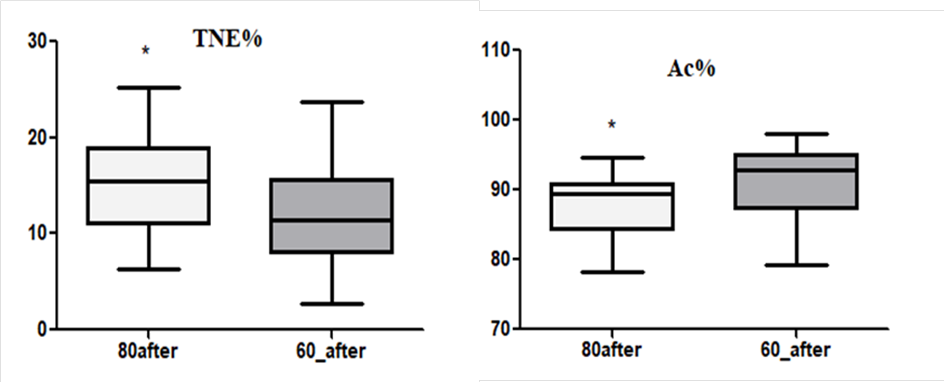
The dynamics of changes are also typical for **RDCF\_aeT**(sec.)- for correctly pressed control characters and **WDOF\_aeT**(sec.)- analysis of incorrectly pressed ordinary characters within the task completion time values, and, unlike the 60-minute duration session, after the 80-minute session, a growing trend in the mentioned indicators is recorded (Fig. 4).

It should be noted that the indicators presented to assess the functional state of brain structures and ensure the implementation of cognitive processes. Within the implementation of the latter, psychological processes related to perception, cognition, comprehensive analysis of information and subsequent motor reactions are consistently involved (Anokhin et al., 1979; Parsons et al., 2004):

**3.2 Comparative changes in functional attention indicators after distant learning sessions lasting 80 and 60 minutes**

Among the functional indicators of attention, the following were evaluated: **Ac%** (the indicator of test accuracy), **CI%** (the attention concentration indicator) determined by the difference in the number of correctly and incorrectly pressed characters (CCS-IC), where CCS is the actual number of correct answers, **TNE%** total number of errors, number of incorrectly omitted **IMS%** and incorrectly pressed **ICS%** characters, and **M\_Cap** (c.u.) (the level of mental capacity).

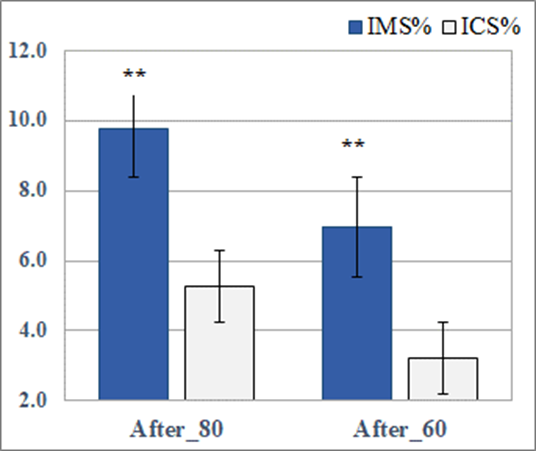
Unlike the 60-minute duration session, after the 80-minute lesson, a decrease is recorded in the **Ac%** test accuracy and total number of errors **TNE%**, forming up to 8.9% (p<0.05) and 15.2% (p<0.05) respectively. Graphical illustration of indicators is shown in Fig. 5.



**Fig. 5 The diagram of the dynamics of the indicators under research at two of the post-session stages.**

Acronyms are: Ac% is the test accuracy indicator expressed as a percentage TNE% total number of errors. The ordinate axis shows the Ac% և TNE% values. On the abscissa axis, Ac% and TNE% indicators are depicted in the post-class phases of the research. Where: the \* is the reliability at the level of p<0.05.

A regular change in the indicators expressing the number of missed IMS% characters and incorrectly pressed ICS% characters is observed. Thus, after an 80-minute lesson, compared to a 60-minute lesson, the IMS% and ICS% indicators significantly increase by 26% (p<0.01) and 28% (p<0.01), respectively (Figure 6). It should be noted that an increase in IMS% indicates the onset of fatigue, distraction, or decreased concentration, while an increase in ICS% means that after a long-term lesson process, students' differentiation between correct and incorrect marks during the test has worsened.



**Fig. 6 Diagram of the dynamics of the indicators studied in the two post-class stages.**

Designations: IMS% indicators characterizing the number of missed and ICS% incorrectly pressed characters. The ordinate axis shows the values ​​of the indicators in percentage terms. The abscissa axis shows the stages of the research. \*\* - reliability at the p<0.01 level. The error bars of the sample are given according to the standard deviation of the mean.

The dynamics of changes are typical also for the M\_Cap (c.u.) level of mental performance and the CI% attention concentration index. As a result of the intergroup comparison, a significant decrease in the latter was recorded, forming up to 21,6% (p<0,05) and 13,4% (p<0,01), respectively (Fig. 7).



**Fig. 7** **The diagram of the dynamics of the indicators under research at two of the post-session stages**.

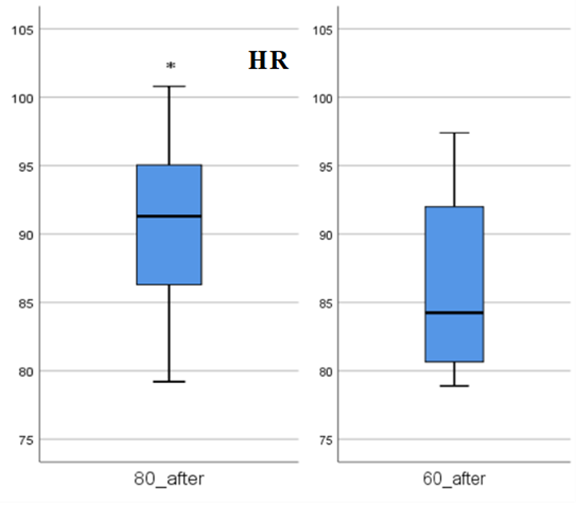
CI% is the attention concentration indicator; M\_Cap (c.u.) is the mental capacity indicator. The ordinate axis shows the CI% և M\_Cap (c.u.) values. The abscissas plot the CI% and M\_Cap indicators in the post-class phases of the study. Where: the \*\* is the reliability at the level of р<0,01 \* p<0,05. The error bars of the sample are given according to the standard deviation of the mean.

Thus, an intergroup comparative analysis of sessions lasting 80 and 60 minutes revealed noticeable changes in the processes of cognitive, in particular, volitional attention.

In comparison with short-term enforced distant learning, along with the decrease in the amount of information perceived and analyzed during long-term enforced distant learning, an increase in the time-based criteria of the analysis of such information is recorded. That is, there is a slowdown in neurodynamic processes due to fatigue and learning load, which has a negative impact on the effectiveness and concentration of attention processes.

**3.3 Comparative changes in HRV indicators after 80- and 60-minute duration sessions**

The changes in heart rate (HR) after classes lasting 80 and 60 minutes during the two phases of the study is presented. The neural and humoral effects of heart rate regulation cause changes (increase or decrease) in the R-R intervals between two heart contractions. It is shown that after an 80-minute duration session, there is a significant increase in heart forming by 5.1% (p<0.05). The slight fluctuation in the heart rate after the long-duration session indicates a relatively stable nature of the manifested tachycardia. After the 60-minute session, the HR was maintained at a normal level (Fig. 8).

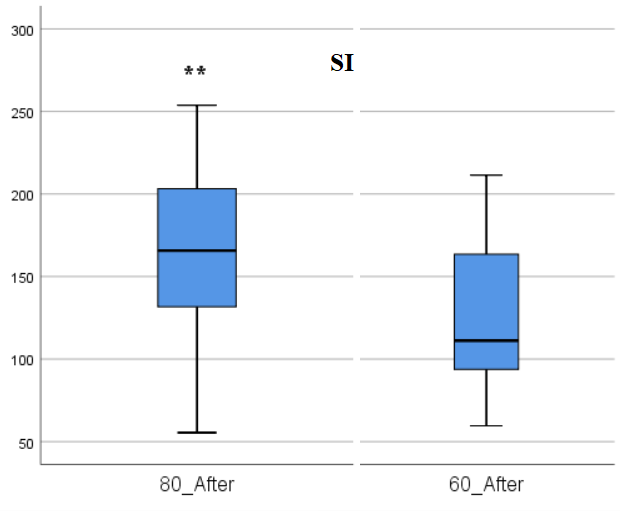
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**Fig. 8 Changes in HR before and after an 80- and 60-min biochemistry class.**

The ordinate axis shows the absolute values of the indicators. The abscissa axis shows the phases of the study. The hyphens of the error in the series line are given according to the standard deviation of the average. Where: the \* is the reliability at the level of р<0,05

The dynamics of changes are also typical for the SI indicator, which manifested in the values of 30.24%(p<0.01). The SI reflects the degree of concentration required for cerebral control of the heart rate, which occurs with the involvement of sympathetic mechanisms. The latter is most typical for stress tests. Higher SI indicators reflect the predominance of retained sympathetic activity in HR regulation systems and the maximum concentration of higher levels of regulation.

In our experiments conducted at two post-session stages, the indicator presented after the more extended 80-minute duration session, in comparison with the 60-minute session, do show higher values, which indicates the processes occurring with sympathetic activity, the predominance of the latter and pronounced stress and tension in the body. The dynamics of changes in SI indicator are shown in Fig. 9.

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**Fig. 9 Diagram of SI, the stress index at two post-session phases.**

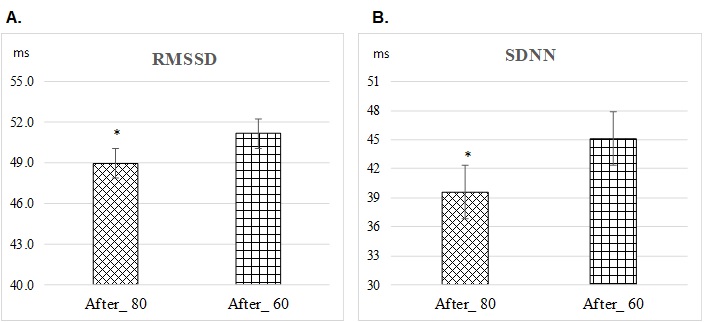
The absolute values ​​of the indicators are depicted on the ordinate axis. On the abscissa axis, SI indicator is depicted in the post-class stages. \*\* - reliability after 80-60 minute lessons at p<0.01 level. The sampling error bars are given by the standard deviation of the mean.

In contrast to the 60-minute class, after the 80-minute class, a reliable decrease in RMSSD and SDNN indicators was observed, amounting to 6.2% (р<0.05) and 12.1% (р<0.05), respectively.

RMSSD- is a square root from the sum of squared differences of sequential NN pairs (normal RR intervals). The sinus node's ability to concentrate the heart rhythm can be evaluated by using this indicator. RMSSD mainly reflects parasympathetic activity mediated by the vagus nerve. The increase in RMSSD may mean an increase in vagal efferent drive.

In our experiments, the increase in the index after a 60-minute session in the intergroup comparison indicates the activity of the parasympathetic loop of regulation of the cardiovascular system (Fig. 10 A).

SDNN is a cumulative index of RR variability over the period under study. SDNN reduction suggests activation of sympathetic regulation that inhibits the autonomic loop. A decrease in the index after a long-term 80-minute lesson shows the dominance of sympathetic activity in learners (Fig. 10 B).

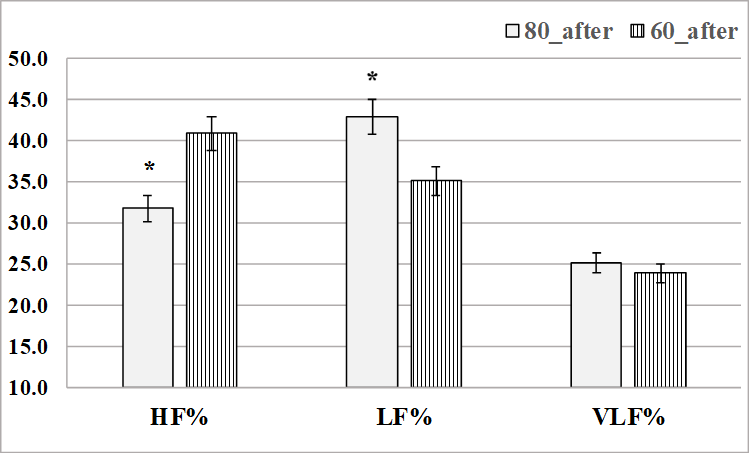


**Fig. 10** **Diagram of the standard deviation of cardiointervals of heart rate variability in the two post-class phases, SDNN (B.) and the root mean square difference between consecutive R\_R cardiointervals, RMSSD (A.).** The absolute values ​​of the indicators are depicted on the ordinate axis. On the abscissa axis: the stages of the study. \* - reliability after 80-60 minutes of lessons at the level of p<0.05. The error bars are given according to the standard deviation of the mean.

It is known that spectral analysis allows to quantitatively assess the involvement of each of the frequency components of heart rate fluctuations in the dynamic changes of cardio intervals. In our experiments, credible changes were also recorded in the spectral LF (%) and HF (%) indicators.

In contrast to the 60-minute session, after the 80-minute session, the relative value of LF increased by 9.36% (p<0.05), and HF decreased by 4.16% (p<0.05) ), which means that in the loops of heart rate regulation after an 80-minute session, a certain involvement of the central loops of regulation and a predominance of sympathetic activity are observed.

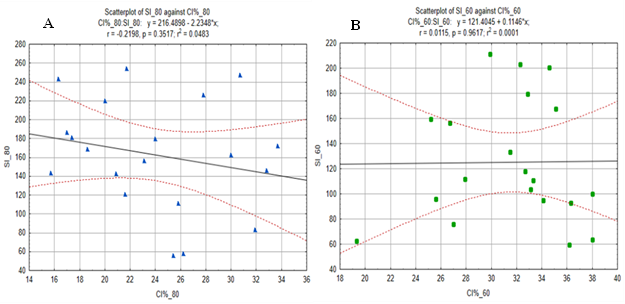
No reliable changes were recorded in the relative value of VLF (%). A graphic representation of the indicators is presented in Fig. 11.



**Fig. 10. Changes in spectral indices of heart rate variability in the two post-class periods.**

The ordinate axis shows the values of the indices. The abscissa axis shows the spectral indices in the study periods.\* - reliability after 80-60 minute classes at the p<0.05 level. The error bars of the sampling series are given according to the standard deviation of the mean.

The study also conducted a regression analysis to assess the relationship between the concentration index (CI%) and the stress index (SI).



**Fig. 11 Scatterograms of linear regression analysis of the two post-training phases: A (80 minutes) and B (60 minutes).**

In the regression model, the stress index (SI) was taken as the independent variable, and the concentration index (CI) was taken as the dependent variable. The figure shows the correlation coefficient (r), the coefficient of determination (R2), the confidence level with a 95% confidence level, the regression equation, and the level of reliability.

During the comparative analysis conducted in the work (linear regression analysis), a certain correlation was revealed between cognitive, volitional attention and heart rhythm regulation processes. Thus, negative correlations were found between the concentration index (CI%) and the stress index (SI) after an 80-minute lesson process (A), which were not observed after a 60-minute lesson process (B) (Fig. 11). Our research has shown that after 80 minutes of class, a significant increase in tension in the heart rhythm regulatory systems was recorded, while at the same time a decrease in the level of attention concentration was observed. The presented regression analysis suggests that the changes recorded in cognitive and heart rate regulation processes after an 80-minute class are not random and are due to certain functional changes occurring in the subjects after a long-term class.

**4 | DISCUSSION**

The distant learning, granting excellent prospects and opportunities for humanity, at the same time poses many problems and obstacles, especially during natural disasters and epidemics, when stressful, neuropsychiatric situations are inevitable for students, taking into account the unavailability of the full-fledged life.

In extreme situations, virtual classrooms do require trainees to have a higher level of tension (Basilaia et al., 2020; Favale et al., 2020). The latter reflects the intellectual, emotional and behavioural processes of students, which are characterized by unique psychophysiological features.

The importance of studying the psychophysiological problems in differentiated areas of distant learning (natural sciences and humanities) was further emphasized and accentuated in the context of the COVID-19 pandemic (Ahmady et al., 2020; Yamin, 2020; Rieley, 2020;Tyler et al., 2021)․ A number of studies conducted in European countries aimed at studying the neuropsychological state of natural science students indicate that the abrupt transition from the traditional format to the remote format was characterized by the rush and sharp increase of stress (Son, 2020). They were accompanied by a decrease in information perception, the segregation of the student-teacher/trainee relationship, the dropdowns in career and other processes (Supriya, 2021; Aucejo et al., 2020; Toquero, 2020; Cahapay, 2020; Tammemi et al., 2020). It is noteworthy that the natural sciences are rich with their experimental segments, and the knowledge gained in this direction should be constantly supported by practical experience. The absence of the latter has formed a negative attitude towards distant learning among natural sciences students. Furthermore, according to some authors, the cancellation of laboratory classes became the key driver of the lack of motivation to study in the area of natural sciences (Supriya et al., 2021; Means & Neisler, 2020). Natural science courses have their own characteristics: they differ in content (in particular, the biochemistry course, which is one of the most difficult in the field of biological sciences), students must integrate various elements of learning, such as the ability and skills to master and use the extensive information, perform laboratory activities and solve problems (Taylor et al., 2017; Dries et al., 2017). It looks natural that in the current situation, the precise implementation of psychophysiological and neurophysiological processes, in particular, the sustainability of attention and neurovegetative changes, requires a higher level of tension from students:

The selection of the necessary professional materials, the lack of time to master their workloads, as well as the evidenced and recorded constant fatigue manifested in students as a result of studying on online platforms are reflected in a number of research studies (Ferdyan et al.,2020; Fomina et al., 2020).

The availability of scientific data in this area indicates that the accurate and competent implementation of differentiated segments of distant learning (natural sciences and humanities) in extreme conditions requires the development of a number of mechanisms, including the duration of classes and sessions. Distance learning in emergency situations is not planned in advance since it involves an unexpected transition from the traditional learning format to remote education. In this situation, the most critical and key condition for effective learning is the study of the psychophysiological characteristics of students, in particular, the analysis of the attention process and its separated, individual components. Attention is characterized by choice, consistency, speed of switching from one type of activity to another, allocation, volume, and concentration. The latter is the key prerequisite for ensuring the reliability of the educational process, based on the stability on which the effectiveness of other activities depends (Robison et al., 2020). It is well known that the speed of processing any information by brain structures is primarily preconditioned by the high mobility of nervous processes, i.e. the effectiveness of plastic changes in synapses. This determines the stability of attention processes. In our experiments, after the 80-minute session, a lack of attention against the background of a decrease in brainwork performance and in the level of concentration and cognitive processes were recorded, as well as the decrease in functional reserves of mental activity and attention. After the long-lasting forced educational process, students lost attention, particularly the time spent on decision-making, scheduling, and completing tasks. Natural science students studying under bound learning conditions lasting 80 minutes, unlike a 60-minute session, during the 80-minute post-class testing, have shown a sharp increase in the number of errors and omissions, a significant decrease in the accuracy of the test and concentration, as well as a predominance of sympathetic activity.

It should be noted that the limbic system of the brain undergoes significant changes when performing a correctional proof test. At the same time, the cortical and subcortical structures of the brain (limbic system), involved in both mental activity and attention mechanisms, secure the vegetative (cardiovascular, respiratory systems) changes accompanying the mental activity.

The study shows that the 80-minute duration session, unlike the 60-minute lesson, runs accompanied by changes in sympathy-parasympathetic correlations that ensure the balance of HRV, where the processes of sympathetic mechanisms activation of the involved ANS and the changes in heart rhythm caused by them, as well as the changes in HRV balance, indicate tension and stress in the bodies of students.

Thus, the analysis of the scientific data obtained allows us to state that an 80-minute duration-bound distance learning session is a learning process that requires long-term concentration and is accompanied not only by cognitive load but also by stressful changes that occur in students under the respective influence of that.

**5 | CONCLUSION**

We believe that the duration of training in extreme situations is of crucial importance, and determining the length of study time in accordance with the professional orientation will improve the effectiveness of student learning. The studies in this field should be continuous, and, as a result of detailed and comprehensive research, the accurate and defined ranges of class hours will ensure the competent arrangements on the latter.

**Abbreviations and Acronyms**

c.u. - conditional unit

ECG – Electrocardiogram

ANS – Autonomic Nervous System

HRV – heart rate variability

HRV MA – mathematical analysis of heart rate variability

**Declarations'**

**Availability of data and materials**

Not applicable.

**Conflict of interest**

The authors declare that they have no conflict of interest.

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**Ethics approval and consent to participate**

* The entire testing process was conducted in accordance with the Helsinki Declaration Ethical Principles for Medical Research Involving Human Subjects (M. Ethics Committee of the Heratsi YSMU (N12-1/22)).
* Written informed consents were obtained from all study participants.

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