European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available on-line at: www.oapub.org/edu

DOI: 10.46827/ejes.v9i8.4438 Volume 9 | Issue 8 | 2022

A STUDY OF MENTAL ACTIVITY AMONG HEALTHY MEDICAL STUDENTS USING A VIRTUAL MODEL TO INVESTIGATE ACUTE COGNITIVE STRESS EFFECTS

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Abstract:
Studies have shown that first-year medical students, experience psychological stress and, in some cases, mental illness due to new environments and stressful study regimes of the medical universities. An experimental study was conducted on first and next (2-3) year medical students of both genders. In the acute stress-recognized virtual model, participants were exposed to two increasing complexity visual tasks. Some derivative indices: correct answers in percent (CA%), reaction sustainability (RS), and functional ability level (FAL) were calculated based on the reaction time measures during simple and complex sensorimotor reactions (SSMRT, CSMRT). For statistical analysis ANOVA and Bonferroni correction t-test was used. No significant differences were found in mental activity between the two genders in 2-3 year medical students, except for CA% in the males' group during CSMRT which indicates that males concentrate well; There were significant differences in parameters of SSMRT (RS; CA%) and CSMRT (RS; FAL; CA%) between first-year males and females; Significant differences were found also in parameters of SSMRT (RS; CA%) and CSMRT (FAL; CA%) between first and next-year medical students in the females' group and no significant differences between first and next-year medical students in males group. Seems independent of gender, in 2-3 year medical students the sensorimotor and cognitive abilities are almost the same. The better mental performance parameters in the male group of first-year students can be explained only by the presence of certain stress in the female group, which can be related to the difficulty adapting to new environments and stressful learning regimes. In addition, male students are able to concentrate better compared to females on acute visual stress. Our

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results contribute to a better understanding of the psychophysiology of mental activity and further demonstrate how a virtual model can be used to investigate acute cognitive stress effects.

Keywords: acute cognitive stress, visual stimuli, simple and complex sensorimotor reactions time, mental activity

1. Introduction

Studies have shown that medical students, especially first-year students, experience psychological stress and, in some cases, mental illness due to new environments and stressful study regimes, which negatively affects their ability to study, their academic performance and full participation in life (Guthrie, Black, Shaw, Hamilton, & Creed, 1998), (Moffat, McConnachie, & Ross, 2004). On a personal level, this stress can contribute to the emergence of cynicism in students, which in turn can have an impact on student behavior, their relationship with professors, and, ultimately, diminishing one's capabilities and the importance of a future profession (Dyrbye, Thomas, & Shanafelt, 2005). The success of the person during the study period depends on the specific ability to maintain the required cognitive-functional level during the long period of study. There are publications using a visual and auditory reaction time (RT) of adolescents with respect to predicting their academic achievements (Taskin, 2016). The study of temporal ratios of activity of mental processes is important in several aspects. The sensor and motor periods in RT mainly are reflective, a cognitive component is related to the decision-making process period. RT increases at the expense of cognitive processing of information, which is related to the processes of identification and through which the stimulus is assigned to a certain category. The difference between the means of the complex (choice) sensorimotor RT (CSMRT) and of simple sensorimotor RT (SSMRT) reflects the speed of the course of nervous and mental processes in the central nervous system (Hick, 1952). The analysis of simple mental RT, allows for determining the relationship between psychological and physiological factors. It shows a person's mental abilities, based on his subjective observations, to objectively perceive the environment. To investigate the parameters of RT, it is possible, on the one hand, to assess the activity of human mental processes, situational attention, perception, and working memory, and on the other hand, to make predictions about adaptation to stress, since, when individuals' resources are insufficient to cope with a relevant situation, stress or anxiety occurs.

2. Literature Review

There are some studies investigating acute cognitive stress effects using virtual models based on the Psychology Experiment Building Language (PEBL-http://pebl.sourceforge.net/) (Fox, Mueller, Gray, Raber, & Piper, 2013), (McDuff,

Hernandez, Gontarek, & Picard, 2016). Considering the interaction of RT time can improve and refine a person's teaching methods so that can better adapt to daily life (Riemann & Lephart, 2002). The study of the time relationship between SSMRT and CSMRT is an indirect indicator of neuronal efficiency. It demonstrates the effectiveness of neural apparatus interactions and information processing. Interestingly that males had a faster RT compared to females for both auditory and visual stimuli (Shelton & Kumar, 2010). A study on 100 first-year medical students (50 males and 50 females) found the same results (Prabhavathi, et al., 2017). In addition, students with higher academic achievement reported faster RT, indicating that attention, concentration, receptor excitation levels, and information processing speed are important for students' success in the learning process and cognition (Rajprabha, Mahima, Sudhanshu, & Anamika, 2019). It is established that effective learning is achieved by the student's focus or ability to focus on a specific goal. The study of total RT and its components is used as a tool for analyzing the mechanisms of cognitive processes and assessing the functional state of the central nervous system in cognitive psychology (Sanders, 1998).

Studies have been conducted where RT parameters are used to better perform mental activities, make decisions, and optimally plan daily life, which is essential for managerial, sports, and other activities that require great attention and instant decision-making skills (Draper, McMorris, & Parker, 2010), (Collardeau, Brisswalter, Vercruyssen, Audiffren, & Goubault, 2001), (Audiffren, Tomporowski, & Zagrodnik, 2008). A large-scale study of a group of people of different ages found correlations between psychometric intelligence and simple reaction time (Deary, Der, & Ford, 2001). Inattention, noise, sharp light, an emotional mood of the tempted person, fatigue, etc. may prolong RT and/or alter its distribution.

There are several mathematical models to process RT. In recent studies, it has been found that standard deviation is more correlated with mental ability scores than the RT mean this is due to the fact that under constant conditions of the experiments, multiple measurements of RT of any individual reveal significant variations of this parameter and their individual values may differ from the mean value by 1.5–2 times (Ratcliff & Tuerlinckx, 2002), (Sternberg & Benjamin, 2015). Individuals with high mental ability have fewer variable responses or fewer standard deviations. The standard deviation rate indicates the degree of balancing of neural processes; the smaller the standard deviation, the more balanced the nervous system (Ravenzwaaij & Brown, 2011). To obtain more complete information about the properties and condition of the mental activity and to determine its functional reserves, additional indicators based on Whipple's index of concentration can be used that are elaborated in demographic statistics to determine non-standard statistical indicators. Among those is the Accuracy index that calculates the number of answers of the test subjects on the stimuli: correct, incorrect and missed answers:

$$KT = \frac{N-R}{N+P}$$

where:
N - presented signals,
R - number of correct answers,
P - number of errors.

The accuracy index indicates the degree of stability of the subject's concentration of attention, which in turn is due to the strength and balance of neural processes (Spoorenberg, 2007). Next, some quantitative criteria have been developed based on the temporal readings of the simple sensorimotor response which allows for characterizing the existing functional state of the central nervous system/mental activity in different ways (https://studme.org/101602/ekologiya/psihofiziologicheskie_metodiki), (Bobrova, 2015).

Based on the above the aim of our research was to study some parameters of mental activity in the first and next (2-3) years of healthy medical students of both genders, based on SSMRT and CSMRT to various visual stimuli and reveal acute cognitive stress effects and possibly inadequate adaptation of students on the new environment, using an experimental virtual model.

3. Material and Methods

A total of 38 DTMU students (17 males, 21 females), aged 18 to 22 years participated in the study. Written consent was obtained by all participants of the study. A brief history was filled in for each participant, indicating basic physical parameters and objective test data.

The study was conducted in a specially designed light and sound-shielded experimental room at the central scientific research laboratory (CSRL) of DTMU. The research was carried out using a block and between-subject design. The research subjects were divided into 2 blocks, i.e. groups: in group A were included first (A1) and 2-3-years male students (A2); in Group B, first (B1), and 2-3-years female students (B2).

The test subjects were placed in room 1-2 times, and several subjects participated in the experiments several times, at intervals of several days, to avoid the experience of the previous experiment. Testing was conducted in the afternoon, after lectures, i.e. all students experienced some fatigue.

The study included physically healthy, right-handed subjects who did not wear glasses and had no visual impairment (controlled via using a "Lotmar visometer" to measure and quantitatively determine the functional value of visual acuity norm - https://leatest.com/vision-test-system/visual-acuity-tests/), who had no history of head trauma and did not take alcohol, coffee, or any medication for the previous 2 days.

The participants were seated in front of a computer, in a comfortable chair, positioned 50 cm away from a computer monitor. The study was preceded by a 10-minute period of adaptation to the local environment. All data were collected on another computer, outside of the experimental room. Each participant was recorded for 25 minutes (with 5 subsequent stages) and was exposed to two 5-minute increasing

complexity tasks (stress condition), each preceded by a 5-minute relaxation period and finished by a 5-minute recovery period. Prior to testing, subjects were instructed in detail about the test and were required to respond to stimuli as quickly and accurately as possible during the test period by clicking the mouse.

The virtual model of the test is designed and programmed by CSRL staff and is based on the „Python language" and the Psychology Experiment Building Language-PEBL (http://pebl.sourceforge.net).

Acute stress was elicited using an image of Landolt's broken ring (https://www.stereooptical.com/wp-content/uploads/2018/07/OPTEC-PLUS-Summary-of-Tests-v5-03-2018.pdf) on the computer monitor. The width of the intermittent rings is 8 grades, exposition of the image - 35msec, the interval between them - 1.5sec, the strength of lightning -90ml candle. During the first task light rings with 3 or 5 cuts, was appeared on a dark screen in one cadre's exposition in a central fixation. A simple sensorimotor response involves pressing the left mouse button with the index finger on the appearance of rings with an odd cut. During the second task, the rings with 3-5 or 4 cuts with different positions appeared in randomized order. The participant had to press the left button if appears an odd number of rings and the right button in the case of even numbers respectively. Each motion mistakes and reaction time associated with performing the above-described tasks are calculated.

The program performs the calculation of the following parameters:

- RT during simple and complex sensorimotor reactions;
- Total number of answers;
- Number of correct answers;
- Number of correct answers in percentage – CA (%);
  (https://studme.org/101602/ekologiya/psihofiziologicheskie_metodiki);

The following derivatives are calculated based on the RT histograms (Bobrova, 2015):

a. System function level:

$$SFL = \ln 1/T_{mod} * \Delta T_{0,5} (C^2)$$

b. Reaction sustainability, that is defined as the stability of the central nervous system:

$$RS = \ln P_{max} / \Delta T_{0,5} (C^{-1})$$

c. Functional Ability Level, that allows to assess the capabilities of the central nervous system:

$$FAL = \ln P_{max} / \Delta T_{0,5} * T_{0,5} (C^{-2})$$

where:

P_{max} - is the number of most frequently repeated reactions – amplitude of mode;
0,5 P_{max} - half of the maximum number of reactions;
ΔT 0,5 - the range of the most frequently repeated reactions.

Figures 1, and 2 show the variation curves during SSMRT and CSMRT.

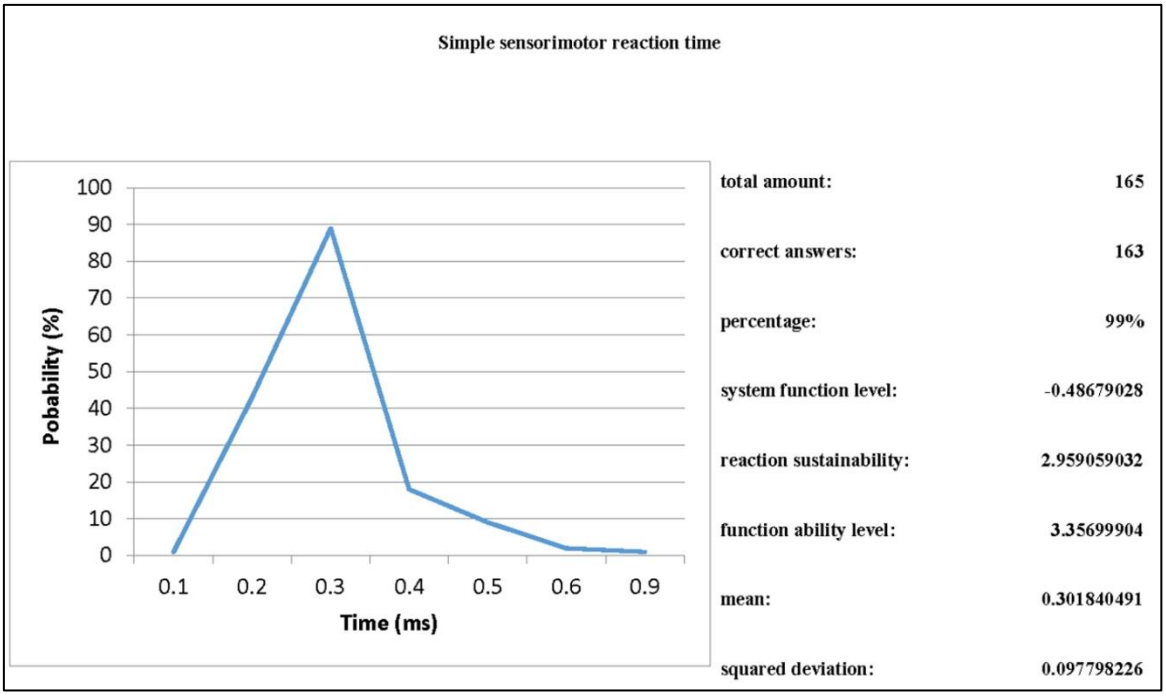

Figure 1: Variation curve of simple sensorimotor reaction time

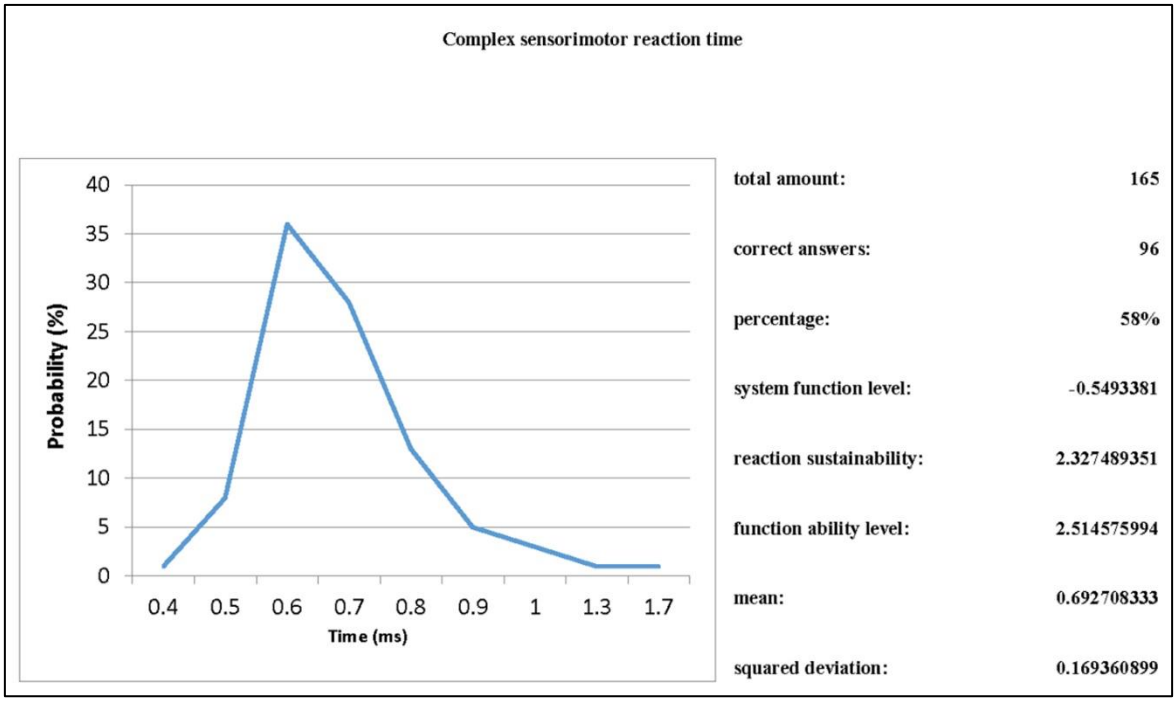

Figure 2: Variation curve of complex sensorimotor reaction time

Where, the ordinate is denoted by the probability - P of occurrence of each value of RT, on the abscissa - the value of RT in ms, next calculating above mentioned derivatives.

For statistical analysis of data obtained, "Primer of Biostatistics" by Stanton A. Glantz, software version 7 was used, based on one-way analysis of variance - ANOVA and multiple comparisons via Bonferroni adjusted t-test with respect to the results of the homogeneity of variance. The significant level was taken as 0.05.

4. Results and Discussion

We computed all the above-mentioned indices for use as features in the cognitive stress recognition model and compared the effects of various acute stress between different groups of participants, to reveal their mental states in each case.

In Table 1, the means, standard deviations and source of variations of RS, FAL and CA (%) during simple and complex sensorimotor reactions in the males (A1, A2), females (B1, B2) as well as first-year students (A1, B1) and 2-3-years students (A2, B2) of both gender groups are shown:

Table 1: Comparison of means, standard deviations and source of variations of RS, FAL and CA (%) during SSMRT and CSMRT in all groups (A1, A2, B1, B2) via ANOVA

N	**Groups**	**SSMRT**			**CSMRT**		
		RS	FAL	CA %	RS	FAL	CA %
18	A1	6±0.9	6.6±1.4	96.11±4.8	5.3±1	6.3±1.5	56.3±3
22	A2	5.6±1	6.2±1.5	92.1±7.2	5.2±0.5	6.1±0.9	58.1±4
10	B1	4.6±0.8	4.8±0.9	78.2±11.8	4.3±0.7	4.8±0.9	48.1±6.9
21	B2	5.7±1.1	6.2±1.6	92±2	5.2±0.9	6.1±1.4	54.7±6.4
Between groups	SS	13.08	21.86	2153	7.85	16.8	715.9
Between groups	DF	3	3	3	3	3	3
Between groups	MS	4.36	7.29	717.7	2.61	5.6	238.6
Within groups	DF	67	67	67	67	67	67
	F	4.40	3.54	10.94	4.01	3.70	9.14
	P	0.007	0.019	0.000	0.011	0.016	0.000
A1/A2	t	0.000	0.000	2.198	0.000	0.000	0.871
B1/B2	t	3.698*	2.565	5.909*	0.000	2.992*	4.323*
A1/B1	t	3.602*	2.499	7.527*	4.436*	2.915*	5.614*
A2/B2	t	0.000	0.000	0.000	0.000	0.000	2.722*

Where:
N - indicates the number of recordings;
SS - Sum of squares;
DF - Degrees of freedom;
MS - Mean squares;
F - F value,
P - P value,
t - adjusted t-test;

*indicates statistically significant differences.

As shown in Table 1, when comparing subgroups of A1 and A2, there are no statistically significant differences between first and 2-3-years students in the males' group.

As seen when comparing subgroups of B1 and B2 in the females' group, statistically significant differences were observed in RS and CA% during SSMRT and in FAL and CA% during CSMRT, which indicates better results for 2-3-years female students compared to first-year female students.

As seen when comparing the data of first-year males and females (A1, B1), statistically significant differences were found in all parameters except FAL during SSMRT, which indicate the better results revealed in males' subgroup compared to females.

In the case of 2-3 year students, the parameters for males (A2) and females (B2) were almost equal. Males have a better significant result only by the number of CA (%) in the case of a complex sensorimotor reactions.

As is clear from the results of the study, first-year medical males showed better results on the average of different parameters of mental activity compared to females. Subsequent courses for both male and female students' groups result in almost equal findings.

In terms of the number of correct answers (%), during both reactions, males responded more accurately than females. That indicates that males are able to concentrate well. This parameter, as already mentioned, indicates the degree of stability of the subject's concentration of attention, which in turn is due to the strength and balance of neural processes, or we can say that males have a more mobile nervous system.

The results of the study partly coincide with the publication cited in the section introduction (Guthrie, Black, Shaw, Hamilton, & Creed, 1998), where the study of both genders of medical students has found that first-year stress is significantly higher than second-year stress and this stress is more associated with stressful learning related to a lot of learning materials and with fear rather than with any personal problems, i.e. the problem of adapting to a new environment, which is no longer observed in later years.

Our results coincide with the study (Moffat, McConnachie, & Ross, 2004) that shows there are some variations in gender, to use active coping strategies in a front of stressors.

Our results extend and coincide with the results of an article reviewing research in this area, published by the Mayo Clinic (Dyrbye, Thomas, & Shanafelt, 2005), where the authors note that stressful teaching can have unintended negative effects on the mental and emotional health of medical students.

The results obtained coincide with the results of studies, which found that males have a faster RT than women for both auditory as well as visual stimuli (Shelton & Kumar, 2010).

The received results coincide with a (Prabhavathi, et al., 2017) conducted on first-year 50 male and 50 female students that also found, that male medical students had a faster RT than women, in the case of both stimuli.

Our results coincide with the study that revealed in generally males and females did not differ significantly in RT settings (Rajprabha, Mahima, Sudhanshu, & Anamika, 2019).

The results obtained confirm earlier results of the study (Draper, McMorris, & Parker, 2010), where was to examine the effect of acute, short-duration exercise on the performance of simple and choice visual reaction and movement times, which revealed that simple and choice reaction times, were affected differently by the acute, short-duration exercise of differing intensities.

The received results confirm the concept by Jensen (Jensen, 2006) who argued the use of RT tests is probably the greatest advantage in monitoring cognitive efficiency.
Our results confirm also the concept by Sanders (Sanders, 1998) who demonstrated that issues of reaction processes and attention are closely interconnected.

Our results extend the results of the studies performed on medical students in a Problem-Based Learning Curriculum (PBL), which revealed, that stress in junior medical students was more likely to be medical training-related (Moffat, McConnachie, & Ross, 2004), (Dagistani, Hejaili, Binsalih, Al Jahdali, & Al Sayyari, 2016).

5. Recommendations

Our results contribute to a better understanding of the psychophysiology of mental activity, further demonstrate how a virtual model and some mathematical measures can be used to investigate acute cognitive stress effects on mental activity and opens up new possibilities for assessing situational attention, perception, working memory, and predicting a person's adaptation to education-related stress.

Based on the research conducted, the following recommendations can be made for the prevention of stress-related problems during the education process. To overcome the stress, especially in junior medical students it is desirable:

- Consult a psychologist;
- Encourage physical activity in female students;
- Involve them in various sports and creative groups affiliated with the University.

6. Conclusion

Interpretations of the received results are summarized here:

- Independent of gender, in second-and third-year medical students the sensorimotor and cognitive abilities are the same.
- The better mental performance parameters in the male group of first-year students can be explained only by the presence of certain stress in the female group, which can be related to the difficulty adapting to a new environment.

- Male students are able to concentrate better compared to females on acute visual stress.

Conflict of Interest Statement
The authors declare no conflicts of interest.

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