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AN ANALYSIS OF THE EFFECT OF THE BODY VIBRATIONS ON THE HUMAN PERFORMANCES

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ABSTRACT

In this paper, we wanted to check if classical music can improve the intellectual and practical skills of those who work in very difficult conditions. For this, we exposed 44 male students, aged 21-24, with normal BMI (19-24), in perfect health, to four types of stressors, when there is classical music as a sic sound background and when we have no music. The stressors used were vibration, excessive temperature, and humidity as well as very strong light. Two pieces of music were chosen as background: "Eine Kleine Nachtmusik" (Mozart) and "Minuetto" (Boccherini). These 2 musical works were chosen because they are cheerful, optimistic, written in an alert rhythm, easily recognizable even if the audience is not music lovers. Students' performance was measured using 3 tests: the Purdue Pegboard Test, the Stroop Color and Word Test and also Comparing of Names Test. The results show that neither Mozart's music nor Boccherini's music led to an improvement in student performances; on the contrary, better results were obtained when it was silence.

Keywords: Whole Body Vibration, temperature, humidity, light, music, human performances

1. INTRODUCTION

Nowadays, the issue that arises more than ever is that of increasing people's performance at the workplace. If that job requires work in difficult conditions, consideration must be given to protecting people from diseases induced by different types of stressors. There are a number of jobs where several stressors are involved in the same time and solutions are sought for ease of work.

One of the old methods is to put on soft music in order not to create communication difficulties, implicitly accidents. Hence, Rauscher et al. (1993) analyzed the effect of Mozart's music (Sonata KV 448 of which Alfred Einstein said it is: „one of the most profound and most mature of all Mozart's compositions") on the performance of some subjects. Their results were not edifying [1]. Also, it was found that the performance achieved by the subjects was according to personal preference [2]. Steele et al. (1999) resumed the initial experiment of Rauscher et al. (1993), following the same procedural instructions and replicating the procedure of one of the original positive reports, but the results were not conclusive [3].

Jackson and Tlauka (2004) found that most investigations were based on paper tests. They argue that the effect would have value in education if the subjects benefited from performances in real cases also [4]. „Three hypotheses have been advanced to explain this association: Mozart priming the neural pathways used for spatial reasoning, Mozart generally increasing mood and arousal and thus performance, or individuals' preference for Mozart, a different form of music, or even silence leading to an optimal mood for test-taking" [5].

Since then, a number of researchers have addressed this issue: for example, McKelvie and Low (2010) investigated the effect of the same work of Mozart, Sonata KV 448, on some students and found that there was no major effect of music and no significant difference between test scores obtained while listening to Mozard versus those obtained while popular music was listened to [6]. The Mozart effect has also been studied by Steele (2000), Jenkins (2001), Schellenberg (2007), Ho et al. (2007), Pietschnig et al. (2010), MacDonald et al. (2011) and others, without obtaining a clear result [7-12].

2. MATERIALS AND METHODS

2.1. Participants

The experiment was attended by 61 male students between the ages of 21-24, with normal BMI (19-24), who stated in writing that they are in perfect health, have no special personal problems and do not

work physical labour. They were told that they could leave the experiment at any time, without giving any explanation. Of these, 43 are smokers and 2 drinkers (more than 2 glasses of wine / day). No student is familiar with symphonic music.

2.2. Experimental conditions

The experiment was intended to be one that imitates as well as possible, the work in very difficult conditions, therefore it acted simultaneously with several stressors (see figure 1):

a) *Mechanical vibration on the Oz axis, on the whole body (two levels 1.6 and 4.2 m/s^2)* The vibrations were transmitted by a plate mounted on a modal exciter Brüel & Kjær (type 4827), controlled by command unit (type 1056) and amplifier (type 27210) and the power supply unit (type 2830) also from B & K. Those vibrations were measured with acquisition unit NetdB from 01 dB-Metravib, using a triaxial accelerometer (type 356A16) from PCB Piezotronics, mounted at head level [13].

b) *Ambient temperature (5^{0}C and 35^{0}C).* The temperature was varied, using four electric heaters (for the temperature was also considered the Joule effect given by the projectors).

c) *Humidity (65 and 95%).* The humidity was changed using two hot steam humidifiers. The temperature and the humidity were measured with Kestrel 4000 Weather & Environmental Meter [13].

d) *Intense light (500 and 2000 lx).* The light was obtained with three portable LED projector with magnifying glass. The light intensity was measured with the UT383 Digital Luxmeter from UNI-T.

e) *As a musical background (45 dB).* Three cases were chosen:

i) Wolfgang Amadeus Mozart (January 27, 1756 - December 5, 1791): This first movement (5.44 min) of No. 13 Serenade for strings in G Major, KV 525, also known as "Eine kleine Nachtmusik" (which is a smaller symphony: 36.46 min, and the ensemble is reduced to a string orchestra consisting of only 5 instruments: two violins, a viola, a double bass and a cello). This first part is called Serenade - Allegro. It was composed in 1787, at the age of 31, 4 years before the composer's death. The serenade is widely performed and recorded and is one of Mozart's most popular works;

ii) Ridolfo Luigi Boccherini (February 19, 1743 - May 28, 1805): String Quintet in E major, Op. 11, No. 5, G 275 (3.34 min), also known as "Minuetto", was composed in 1771, at the age of 28. This string quintet is a "cello quintet" in that it is scored for a string quartet (two violins, viola, cello) with a second cello as the fifth instrument. Boccherini's style is characterized by Rococo charm, lightness, optimism, and exhibits much melodic and rhythmic invention;

iii) In silence (max. 15dB).

Each experiment lasts 15 min and was carried out in a laboratory of 5.8m x 3.5m x 4.4m in size. These works were chosen (as opposed to the Sonata K 448 used so far) because both music variants represent works of approximately the same type, composed around the same period, by composers of near age; they are cheerful, optimistic, written in an alert rhythm, easily recognizable even if the audience is not music lovers. The music is replayed up to 15 minutes.

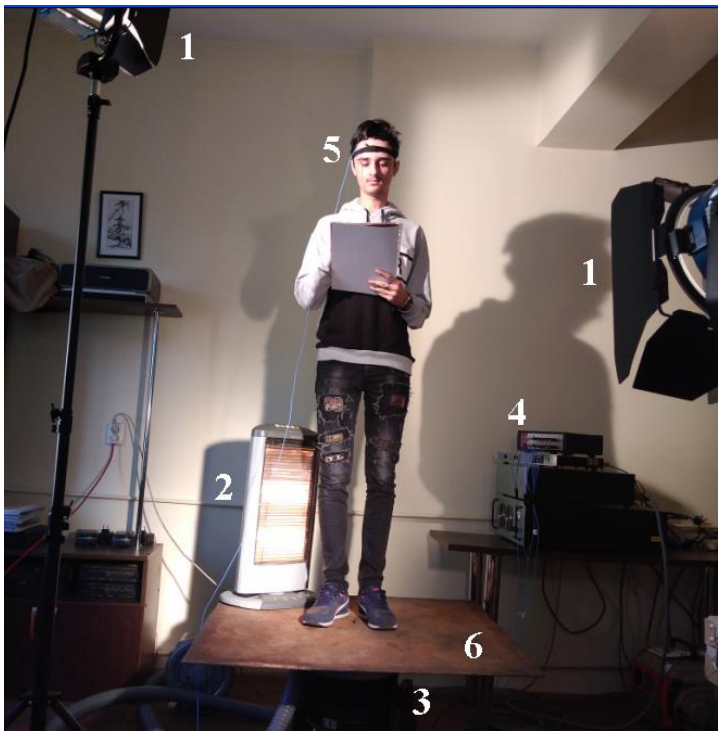

Fig. 1. Subject in experimental conditions: 1-projector, 2-heater, 3-modal exciter, 4-acquisition unit, 5-triaxial accelerometer, mounted at head level, 6-plate mounted on modal exciter

In order to determine how to quantify the action of these external factors on human performance [13], it will be considered that each of the stressors equally concurs to subject's lack of concentration:

$$S_I = \frac{1}{4}\cdot a_m + \frac{1}{4}\cdot T_m + \frac{1}{4}\cdot u_m + \frac{1}{4}\cdot L_m = \\ = \frac{1}{4}\cdot\left(a_m + T_m + u_m + L_m\right) \quad (1)$$

where S_I is the stress (in arbitrary units A.U.) for minimum (m) values of: *a* acceleration of whole body vibration transmitted to the head (m/s^2), *T* temperature (^{0}C), *u* humidity (%) and *L* lighting level (lx), iar S_{II} is the stress (in the same arbitrary units A.U.) for maximum (M) values:

$$S_{II} = \frac{1}{4}\cdot\left(a_M + T_M + u_M + L_M\right) = \\ = \frac{1}{4}\left(2.625\cdot a_m + 7\cdot T_m + 1.46\cdot u_m + 4\cdot L_m\right) \quad (2)$$

2.3. Work performance measurement

The subjects solved the following tests while exposed to the stressors:

- „The Purdue Pegboard test, under the same types of vibration exposure. The Purdue Pegboard test uses a board with two parallel rows, each with 25 holes into which the examinee places cylindrical metal nails. There is a short briefing at the beginning of the test. The subsets for preferred, non-preferred, and both hands require the subject to place the pins in the holes as quickly as possible and the score is the number of pins placed in 30 seconds. The test was repeated 3 times in 3 different days" [13] [14] [15].
- „The Stroop Color and Word Test is a neuropsychological test extensively used to assess the ability to inhibit cognitive interference that occurs when the processing of a specific stimulus feature impedes the simultaneous processing of a second stimulus attribute, well-known as the Stroop Effect" (An example is shown in Figure 2) [16] [17].

Fig. 2. Stroop Color and Word Test [17]

- Comparing of Names Test (An example is given in Fig. 3). This test measures the speed at which a subject links words [16] [18].

bitter	lemon
sour	pepper
spicy	cake
salted	water
sweet	wormwood
tasteless	cheese

bitter	wormwood
sour	lemon
spicy	pepper
salted	cheese
sweet	cake
tasteless	water

Fig. 3. Comparing of Names Test [18]

To study the effect of temperature, humidity, noise level and whole-body vibrations on human performance, the working scheme in Table 1 was used.

3. RESULTS AND DISCUSSIONS

During the experiments, 17 subjects dropped out at different stages. For this reason, the result will refer only to those left to the end: 44 subjects. The tests they had to solve are: The Purdue Pegboard Test (max 25 holes), The Stroop Colour Test (max 18 words) and Comparing of Names Test (max 6 words). The test was repeated 3 times in 3 different days.

3.1. The Purdue Pegboard test mediated results

Figure 4 shows the mediated result of the number of holes pinned by the 44 subjects for the 3 identical Purdue Pegboard tests, repeated in 3 different days (see also table 2).

For the Mozart background sound, in the case of experiment A (■), it is seen that 11 subjects pinned 20 holes and 10 subjects pinned 21 holes (47.72% of the total subjects), whereas in the case of experiment B (□), only 5 subjects pinned 20 holes (11.36%); in this case it is worth mentioning that others 10 subjects pinned 18 holes.

For the Boccherini background sound, in the case of experiment C (▲), it is seen that 12 subjects pinned 20 holes, 2 subjects pinned 21 holes and 8 subjects pinned 22 holes (50% of the total subjects), while in the case of experiment D (□), only 6 subjects pinned 22 holes (13.63%); and in this case we mentioned that another 12 subjects had 18 holes each.

Table 1. Working scheme

Musical background	**Eine kleine Nachtmusik max 45 dB**		**Minuetto max 45 dB**		**Silence max 15 dB**	
Experiment number	*A*	*B*	*C*	*D*	*E*	*F*
Acceleration a_z (m/s^2)	1.6	4.2	1.6	4.2	1.6	4.2
Temperature (^{0}C)	5	35	5	35	5	35
Humidity (%)	65	95	65	95	65	95
Lighting level (lx)	500	2000	500	2000	500	2000
Stress	$\mathbf{S_{I-M}}$	$\mathbf{S_{II-M}}$	$\mathbf{S_{I-B}}$	$\mathbf{S_{II-B}}$	$\mathbf{S_{I-S}}$	$\mathbf{S_{II-S}}$

where in Stres, the index M refers to Mozart, B to Boccherini and S to Silence.

In the situation when the determinations were carried out in quiet conditions, experiment E(●), the results were similar in the case of experiment C: 22 subjects (50%) pinned over 20 holes, but the distribution was the most balanced. Surprising was the last result (experiment F(○)), that is 12 subjects (27.27%) pinned more than 20 holes (4 subjects pinned 20 holes and 8 subjects pinned 21 holes), double number compared to cases B and D.

3.2. The Stroop Color and Word Test

Figure 5 shows the mediated result of the number of words correctly matched by the 44 subjects for the 3 identical Stroop Colour and Word tests, repeated in 3 different days (see also table 3).

For the Mozart background sound, in the case of experiment A (■), it is seen that 15 subjects matched 15 words, 9 subjects matched 16 words and 2 subjects matched the maximum number of 18 words (50.09% of the total subjects), while in in the case of experiment B (□), only 2 subjects matched 15 words (4.54%); in this case it is worth mentioning that 12 subjects matched 14 words.

For the Boccherini background sound, in the case of experiment C (▲), it is seen that 17 subjects matched 15 words, 6 subjects matched 16 words and 2 subjects matched the maximum number of 18 words (56.81% of the total subjects), in while in the case of experiment D (□), only 3 subjects matched 17 words (6.81%); in this case it is worth mentioning that 16 subjects matched 14 words.

In the situation where the determinations took place quietly, the results were surprising in the case of experiment E (●): 29 subjects (65.9%) matched over 15 words, thus: 5 subjects - 15 words, 10 subjects - 17 words and 14 subjects - the maximum number of 18 words. Also, 10 subjects matched 14 words. In contrast, in the case of experiment F (○), the results are very bad for more than 15 words, but it should be noted that 16 subjects matched 12 words and 18 subjects matched 14 words.

3.3. Comparing of Names Test

Figure 6 shows the mediated result of the number of words correctly matched by the 44 subjects for the 3 identical Comparing of Names Test, repeated in 3 different days (see also table 4).

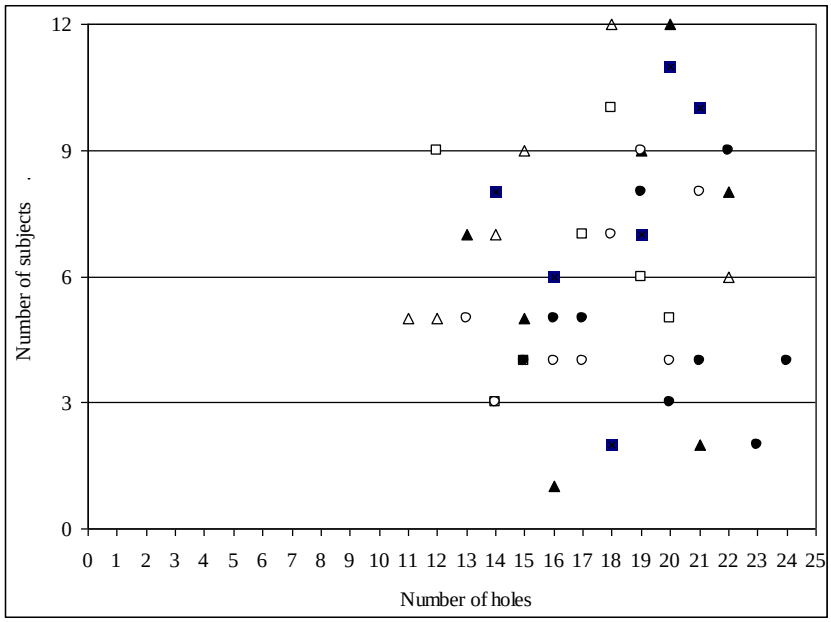

Fig. 4. The Purdue Pegboard Test mediated results.

Table 2. Purdue Pegboard Test results and symbols

Stress		**S_{I-M}**	**S_{II-M}**	**S_{I-B}**	**S_{II-B}**	**S_{I-S}**	**S_{II-S}**
Symbol		■	□	▲	Δ	●	○
Experiment number		*A*	*B*	*C*	*D*	*E*	*F*
The number of subjects who pinned more than 20 holes	20 holes	11	5	12		3	4
	21 holes	10		2		4	8
	22 holes			8	6	9	
	23 holes					2	
	24 holes					4	
	25 holes						
	Total	**21**	**5**	**22**	**6**	**22**	**12**

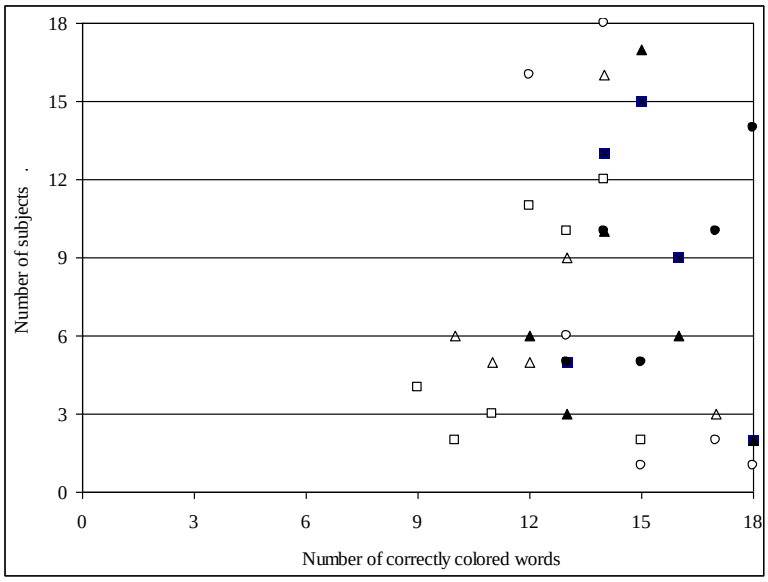

Fig. 5. The Stroop Colour Test and Word Test mediated results.

Table 3. Stroop Colour Test results and symbols

Stress		**S_{I-M}**	**S_{II-M}**	**S_{I-B}**	**S_{II-B}**	**S_{I-S}**	**S_{II-S}**
Symbol		■	□	▲	Δ	●	○
Experiment number		*A*	*B*	*C*	*D*	*E*	*F*
The number of subjects who matched more than 15 words	15 words	15	2	17		5	1
	16 words	9		6			
	17 words				3	10	2
	18 words	2		2		14	1
	Total	**26**	**2**	**25**	**3**	**29**	**4**

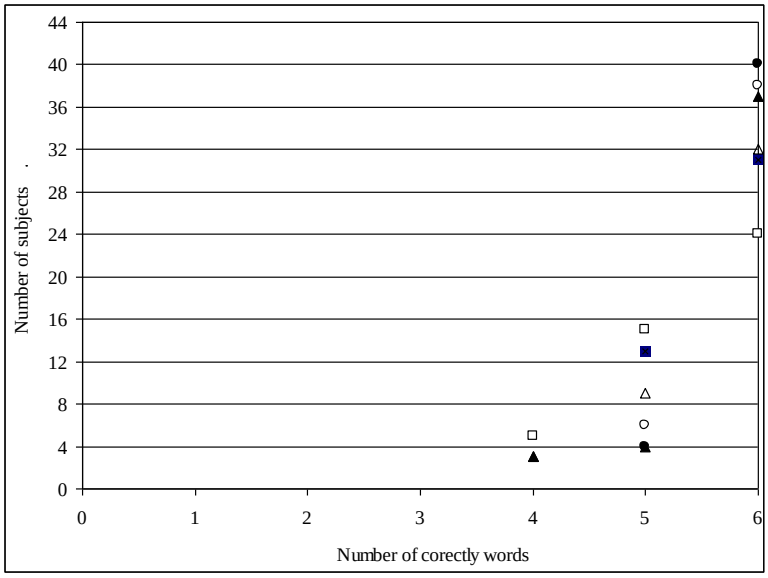

Fig. 6. The Comparing of Names Test mediated results.

Table 4. Comparing of Names Test results and symbols

Stress		**S_{I-M}**	**S_{II-M}**	**S_{I-B}**	**S_{II-B}**	**S_{I-S}**	**S_{II-S}**
Symbol		■	□	▲	Δ	●	○
Experiment number		*A*	*B*	*C*	*D*	*E*	*F*
The number of subjects who matched more than 5 words	5 words	13	15	4	9	4	6
	6 words	31	24	37	32	40	38
	Total	44	39	41	41	44	44

For the Mozart background sound, in the case of experiment A (■), it is seen that 13 subjects matched 5 correct words and 31 subjects matched 6 correct words, meaning 100%. In the case of experiment B (□), only 5 subjects did not match the correct words (11.36%); the remaining 15 subjects correctly selected 15 words and 24 subjects correctly selected all 6 words.

For the Boccherini sound background, in the case of experiments C (▲) and D (□), it is seen that only 3 subjects did not say at least 5 correct words, and 37 subjects, respectively 32 matched the maximum of 6 correct words.

In the situation where the determinations took place quietly, the results were very good: 40 subjects (Experiment E), respectively 38 subjects (Experiment F) matched the maximum of 6 correct words..

4. CONCLUSIONS

It was found experimentally that the power of concentration, the focus on one or more tasks becomes especially difficult, if one works in difficult conditions.

In this case, whole body vibration, temperature, humidity and strong light were the stressors that influenced more or less the results of the tests the subjects took.

It can be concluded that the influence of a certain type of music - in this case Mozart versus Boccherini - did not visibly improve the results obtained during the experiments. On the contrary, better results were obtained when it was quiet.

In fact, the students asked if, instead of the suggested music, they can play their favourite music, at the preferred sound level. Not being allowed to do so, they mentioned that this type of music not only does not generate them a good mood, but it annoys them, and they make efforts to ignore it.

It is worth mentioning that none of the subjects pinned all 25 holes in the first test: Purdue Pegboard.

In the case of the second test, Stroop Color, there were 2 students who reached the number of words in the presence of music and 14 students who reached the maximum number of words in the absence of music. As for the third test, the results were clearly superior, but the test was also simpler. All these relatively satisfactory results were obtained under milder laboratory conditions: acceleration a_z=1.6 m/s^2, temperature=5 ºC, humidity=65% and lighting level=500 lx.

When conditions became more drastic: the acceleration increased 2,625 times, the temperature 7 times, the humidity 1.46 times and the lighting level 4 times, their results were extremely modest.

If, in addition to all these, the real working conditions (not the laboratory ones) are added, it can be said that any incentive that can improve the work and life of a worker, leads to increased productivity.

In conclusion, we cannot say that a certain type of music leads to an increase in intellectual or practical performances, as stated by Rauscher et al (1993) about Mozart's Sonata K 448.

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REFERENCES

[1] Rauscher F.H., Shaw G.L., Ky K.N. (1993) Music and spatial task performance, *Nature,* **365,** 611.

[2] Nantais K.M., Schellenberg E.G. (1999) The Mozart effect: an artifact of preference *Psychological Science* **10**(4) pp. 370-373.

[3] Steele K.M., Bass K.E., Crook M.D. (1999) The mystery of the Mozart effect: failure to replicate *Psychological Science,* **10**(4), pp. 366-369.

[4] Jackson C.S., Tlauka M. (2004) Route Learning and the Mozart Effect *Psychology of Music,* **32**(2), pp. 213-220.

[5] Jones M.H., West S.D., Estell D.B. (2006) The Mozart effect: Arousal, preference, and spatial performance *Psychology of Aesthetics, Creativity, and the Arts,* **S**(1), pp. 26-32.

[6] McKelvie P. and Low J. (2002) Listening to Mozart does not improve children's spatial ability: Final curtains for the Mozart effect *British Journal of Developmental Psychology,* **20**(2), pp. 241-258.

[7] Steele K.M. (2000) Arousal and Mood Factors in the "Mozart Effect" *Perceptual and Motor Skills,* **91**(1), pp. 188-190.

[8] Jenkins J.S. (2001) The Mozart effect, *J R Soc Med,* **94,** pp. 170-172.

[9] Schellenberg E.G., Nakata T., Hunter P.G. and Tamoto S. (2007) Exposure to music and cognitive performance: tests of children and adults *Psychology of Music,* **35**(1), pp 5-19.

[10] Ho C., Mason O. and Spence C. (2007) An investigation into the temporal dimension of the Mozart effect: Evidence from the attentional blink task *Acta Psychologica,* **125**(1), pp. 117-128.

[11] Pietschnig J., Voracek M. and Formann A.K. (2010) Mozart effect-Shmozart effect: a meta-analysis *Intelligence,* **38**(3), pp. 314-323.

[12] MacDonald R.A.R., Kreutz G. and Mitchell L. (2011) *Music, Health and Wellbeing* New York, NY, US: Oxford University Press.

[13] Picu M. (2015) Multi-stress and human performance: a refutation of inverted-U hypothesis,

Journal of Multidisciplinary Engineering Science and Technology (JMEST), **2**(9), pp. 2542-2552.
[14] Picu L., Rusu E.V.C., Picu M. (2019) *An Analysis of How Physical and Social* Factors Influence the Efficiency of Crew Members of a Ship Running on the Danube, *The 15th International Conference „Acoustics & Vibration of Mechanical Structures", AVMS 2019*, Timisoara, Romania.
[15] Picu L., Rusu E.V.C. (2018) Multiple physical stress exposures of sailors on several ships – A longitudinal study, *Annals of Dunarea de Jos University, Fascicle II-Mathematics, Physics, Theoretical Mechanics*, X(XLI) **41**(1), pp 84-93.
[16] Picu L., Rusu E. (2019) Effects of low-frequency noise on crews of river vessels on the Danube, *Mechanical Testing and Diagnosis*, **9**(3), pp. 11-17.
[17] Scarpina F., Tagini S. (2017) The Stroop Color and Word Test *Frontiers in Psychology*, **8,** 557.
[18] Moyer R.S. (1973) Comparing objects in memory: evidence suggesting an internal psychophysics, *Perception & Psychophysics*, **13**(2), pp. 180-184.