Does music help to be more attentive while performing a task? A brain activity analysis.

Ana Rita Teixeira
Coimbra Polytechnic- ESEC, DETI-IEETA University of Aveiro, Portugall
ateixeira@ua.pt

Ana Tomé
DETI-IEETA University of Aveiro, Portugal
ana@ua.pt

Luís Roseiro
Coimbra Polytechnic - ISEC
Coimbra, Portugal
lroseiro@isec.pt

Anabela Gomes
Coimbra Polytechnic - ISEC
Centre for Informatics and Systems – University of Coimbra
Coimbra, Portugal
anabela@isec.pt

***Abstract*—The human brain is one of the most complex physiological systems, involving billions of interacting physiological and chemical processes giving rise to the experimentally observed neuroelectric activity, called electroencephalographic (EEG) signals. A biomedical signal, electroencephalography (EEG), reflects the state of mind and is often used to verify the influence of music on human brain activity. In this paper we present a brief study of various effects of music on Attention and Concentration state of the brain using the Neurosky Mindwave Mobile Headset and EEG Analyser application. The aim of the study is to identify which type of music can help the brain activities to be more attentive while performing a cognitive task (playing a game). In contrast the effects of music in the Concentration state is also studied in order to understand how the music can help the brain activities to be more focused. Although the number of participants was reduced, the results were interesting. The music acts in an individualized way in the performance of each participant. It was found that for certain tasks there is a strong correlation between Attention and Concentration levels. In addition, a distinction between genders of participants can be made according to the results.**

Keywords—Neuroelectrical activity, EEG, Mindwave, Attention level, Concentration level.

I. INTRODUCTION

The basic and one of oldest socio-cognitive domains of Human species is music. Listening to music regularly helps to keep the neurons and synapses more active. The way sound waves are heard or pronounced, may impact how the neurological (brain and nerve) system works in the human body. Neurological studies have identified that music is a valuable tool for evaluating the brain system [1]. However, each type of music has its own frequency, it can either resonate or it can be in conflict with the body's rhythms (heart rate). Each frequency band of EEG relates to specific functions of brain. Beta Waves (14-24Hz) correspond to the typical "busy mind experience". The beta frequency range is characterized by a chaotic, fragmented and unbalanced thinking which is typical of left brain dominance, commonly referred to as the monkey mind. Beta activity relates to increased alertness and cognitive processes. Alpha Waves (8-13Hz) correspond to balanced brainwave activity. The more alpha waves that a person is able to produce in ordinary states of consciousness, the easier it is for them to access deeper meditative states. Theta Waves (4-7.5Hz) correspond to an increase of the balanced brainwave activity. The Theta state corresponds to the experience of visionary, creative and intuitive levels of experience. It is characterized by inner images and visions that correlate with increased Theta activity. Consequently, Theta waves often appear on EEG during consecutive mental tasks. Delta Waves (0.5-4Hz) bring a level of balance that corresponds to beyond the mind experience at the subtest levels of meditative awareness possible. This is the range in which meditators experience what is termed unified consciousness [2-6].

Music has a strong impact on the human body and mind. We believe that music has a direct connection with human feelings and mood. Music is remarkable for its ability to manipulate emotions and stress in listeners [4]. Listening to music increases power at Theta and Alpha frequencies of the human EEG [5]. Most of us listen to music of our choice during our leisure time or while working or studying. Music can be used as a tool to relieve tension/stress, solitude or relax, it also has an ability to enhance the listeners mood [2]. These changes are reflected clearly in the physiological system for the human body. The majority of previous studies are mainly focused on the effect of music on brain functions without any mental workload. Videogames are also considered one of the preferred sources of entertainment. According to the Entertainment Software Association (ESA) annual report, 42% of the population in the United States plays games regularly, generating a total of 15.4 billion dollars in sales. Player's average age is 35 years old and the average time spent playing is 3 hours per week [3]. Therefore, we are interested in verifying the music effects in the levels of Attention and Concentration of individuals doing a workload task (playing a game).

There has been a great deal of research focusing on detecting the Attention state of mind from the

characteristics of EEG [7-13]. The detection of the Attention is important in many fields, including clinical studies of stress reduction, sleep deprivation, fatigue, driving behaviour, educational studies of learner Attention and game studies of player Concentration and engagement. Attention has been defined as the ability to focus our cognitive resources on one relevant aspect of the environment while ignoring other irrelevant aspects [14]. Many BCI-based neurofeedback games [10, 15-16] employ an Attention-related EEG feature as the control parameter, as Attention is a key factor of human cognition. However, automatic determination of the subjects' Attention state is challenging because Attention involves complex human cognitive functions. Previous research [8, 11, 17] has demonstrated evidence that EEG signals (especially the beta band) contain considerable information about Attention, indicating the possibility of recognizing a subjects' Attention level by studying the EEG data.

In this work we designed the experimental protocol to see the effect of music like heavy metal or relaxing music with and without mental workload to measure the Attention and Concentration levels. We used a video game as a mental workload for our experiment.

The results are promising and show that the Concentration and the Attention levels are correlated in some tasks considering the same type of music. In addition, it is possible to see that in some cases the music influences the performance of the participants.

Moreover, the levels of Concentration and Attention vary differently depending on the task, on the music and on the gender of the participants.

The paper is organized as follows: section 2 describes the main steps of the methods, materials and procedures; section 3 presents the results and their discussion; in section 4 some conclusions and further work are presented, and finally section 5 has the bibliography.

II. Methods, Materials and Procedures

Brain Computer Interfaces (BCI) are direct functional interactions between a human brain and an external device [18]. BCI have recently sparked a new interest as a practical Human Machine Interface (HMI). They measure the brain activity of a user and then identify the thought pattern or desired action of the user. Brain activity is measured by detecting minute voltage changes in specific areas of the brain. This can be done in three ways: 1) invasive, where electrodes are placed in the brain itself, 2) partially-invasive where electrodes are placed on the skull and 3) non-invasive where electrodes are placed on the scalp [19]. Electroencephalography (EEG) is the only currently available non-invasive brain activity measuring method and therefore it is the most widely used. It has been shown that using EEG is a viable method of BCI [20].

In this research we have used Neurosky Mindwave Mobile Headset to receive and record the EEG signals during the tests. This BCI device turns our brain waves into actions, unlocking new work of interactivity. The Neurosky Mindwave Mobile Headset reports the wearer's mental state in the form of Neurosky's proprietary Attention and Concentration eSense algorithms, along with raw wave and information about the brainwave frequency bands. Neurosky MindWave Mobile Headset is a low cost and compact EEG (electroencephalogram) device with a biosensor to collect EEG signals from the surface of the scalp which is processed with Neurosky's eSense algorithm and wirelessly transmits the calculated Attention and Concentration values through Bluetooth to a master device at the rate of 1Hz. Its wireless interface makes it ideal for wearable electronic application. The Neurosky Mindwave Mobile Headset picks up our brain's electrical activity and divides the signal by frequency into various types of waves, allowing it to infer our mental state. For most of the non-scientific applicatios however, it primarily reads how relaxed (as measured by alpha/theta waves) or concentrated (as measured by beta/gamma waves) our brain is.

The EEG Analyser is an android application that can read electrical brain activity with EEG technology and blink strength with EMG sensor from Neurosky Mindwave Mobile device. This application is available on Neurosky store website. It has many features that we wanted for our research study for example, reading Attention/Concentration/Blinking strength levels, saving the readings of all three levels and allowing to export the saved data.

The game that we chose for our experiments was 'Despicable Me: Minion Rush', a very popular game amongst the youngsters. The objective of the game is to try to get as far as possible while collecting as many bananas as one can during the run. The reason behind the choice of this game is that it is a very entertaining game and, also, we wanted a game with little mental workload where the player had to pay Attention to the game while playing. Therefore, we consider it suitable for our research as it fulfils both criteria.

In respects to the music, we have selected two completely different types of music, one is Heavy Metal and another is a Relaxing music. Heavy Metal is an intense, massive sound, characterized by highly amplified distortion, extended guitar solos, emphatic beats, and overall loudness. While, on the other side, Relaxing music is used to aid in the practice of Concentration. It is a very calm, instrumental and slow music that we can relax and meditate while listening to it.

In our research we invited 5 students from our college campus and asked them to volunteer for an experimental test. There were 3 boys and 2 girls, and their average age was 19.

To understand the effects of music on Concentration and Attention levels of the brain, we selected 5 different tasks. In Task 1 the user was only playing the video-game; in Task 2 the user was playing the videogame while listening to Heavy Metal; in Task 3 the user was playing the videogame while listening to Relaxing music; in Task 4 the user was just listening to Heavy Metal; in Task 5 the user

was just listening to Relaxing music. Each task was completed separately.

All of the 5 students completed the 5 tasks, individually, in the following order: Task 1, Task 2, Task 3, Task 4 and Task 5. All the tasks were carried out for 2 minutes.

III. Results and Discussion

In this section the results and the respective discussion are presented. In this work, 5 individuals were evaluated in the performance of 5 tasks. In total, we have a set of data that allows us to see the effects of the music in the state of Attention and Concentration of the brain during the execution of each task.

In each sample of data, we have the levels of the Concentration and Attention level recorded during a 2-minute task. In Figure 1 the Attention and Concentration levels, in percentage, for each individual and task is presented. A temporal window of 60 msec is considered, for a better visualization, although the analysis was performed considering 2 minutes. The graphics presented a high variability of the Attention and Concentration levels. To better understand the relation between these two parameters by task and by individual, a comprehensive statistical analysis is done, considering 2-minutes. The average of Attention and Concentration levels for each individual and for each task is computed. In Figure 2 (left bar graphic) we can see that Task 3 is the one that leads to higher levels of Attention and Concentration. However, in the case of the global task analysis by each individual, it is verified that there is not an individual that presents the highest levels, but there is a variation of the maximum levels of Attention and Concentration. Ind3 stands out in the levels of Attention in means and in turn, Ind4 stands out in the levels of Concentration, Figure 2 (right bar graphic).

As we can see in the graph, in Task 1 which was just playing the game and in Task 2 consisting in playing the game with Heavy Metal, the average Attention level of most of the participants dropped during Task 2 compared to Task 1. As Heavy Metal is very loud and fast, this might have affected the participant's Attention level. When we compare Task 3 (playing the videogame while listening to Relaxing music) with Task 2 (playing the videogame while listening to Heavy Metal) we can see that Relaxing music helped the participants to increase their Attention level while playing the game. On the other hand, when we compare Task 4 (just listening to Heavy Metal) and Task 5 (just listening to Relaxing music) which were just listening to music, we had somewhat similar average of Attention levels except in one participant who showed more Attention while listening to Relaxing music than the Heavy Metal.

The Concentration level of participants in both Task 1 and Task 2 is between 38-65, however if we take the average of the five participants during these two tasks, the average Concentration level increased in Task 2 by 4 from 45 to 49. In Task 3 the Concentration level increased more than in Task 1 and Task 2 and it was between 50-60. In Task 4 and Task 5, girl 2 got a clear difference in the Concentration level where she had a higher Concentration level while listening to Relaxing music. The other participants have almost the same level of Concentration while listening both types of music. To summarize the maximum levels of Attention and Concentration in media by task, a table is done where the values and corresponding individuals were considered, Table 1. By the values, we can see that Ind3 in Task 1 presents the highest Attention level (75,2%) and in Task 3 Ind3 also presented a high value (71.60%). Note that Figure 2 shows that Task 3 in average had the highest Attention level. In the case of Concentration parameter, the highest level is in Task 3 for Ind1 (71.07%). In Table 1 we can see that Ind1 never appears as the individual with the highest values of Attention and Concentration in any of the analyzed tasks.

TABLE 1. TASKS WITH MAXIMUM AVERAGE VALUES AND THE CORRESPONDENT INDIVIDUAL FOR ATTENTION AND CONCENTRATION LEVEL IN %.

	ATTENTION		**CONCENTRATION**	
	Individual	***Average***	***Individual***	***Average***
TASK1	Ind3	75.20	Ind4	64.77
TASK2	Ind4	60.03	Ind3	69.78
TASK3	Ind2	71.60	Ind5	71.07
TASK4	Ind2	53.55	Ind4	54.37
TASK5	Ind4	57.33	Ind5	53.15

We also analysed several parameters in order to verify the existence of correlations. The correlation coefficient between Attention and Concentration levels by task and individual is computed (Table 2). A high correlation is visible for Task 2 in all individuals. Note that in this case, Ind4 and Ind5 (feminine gender) present a negative correlation, that means if one parameter increases, the other parameter decreases with the same magnitude, and vice versa. For Ind1, Ind2 and Ind3 (masculine gender) the correlations in Task2 are positive. Through these results, we can infer a pattern associated to the gender of individuals and the influence of music in the performance of tasks. A pattern in Task4 is also visible. The masculine gender has a higher positive correlation in Task 4 (listening to Heavy Metal music).

In the case of Task 5 (Relaxing music), the feminine gender (Ind4 and Ind5) and also the Ind2 have a positive correlation. It is also important to note that Ind2 has a higher correlation in all tasks, except in Task3. It means that the Attention and correlation levels are associated, but in Task3, when individuals play the game with Relaxing music, they aren't. With this result there may be an indication that Ind2 does not focus on parallel tasks with Relaxing music.

The correlation coefficient between tasks was also performed by each individual, Table 3. As shown previously, Ind4 presents the highest levels of Concentration, verified in isolated tasks and between tasks. Task1 and Task2 are correlated in Concentration levels for all individuals, except for Ind3. Ind2 and Ind5 present a

similar correlation in the two parameters considering Task2 and Task3 (playing the game with music).

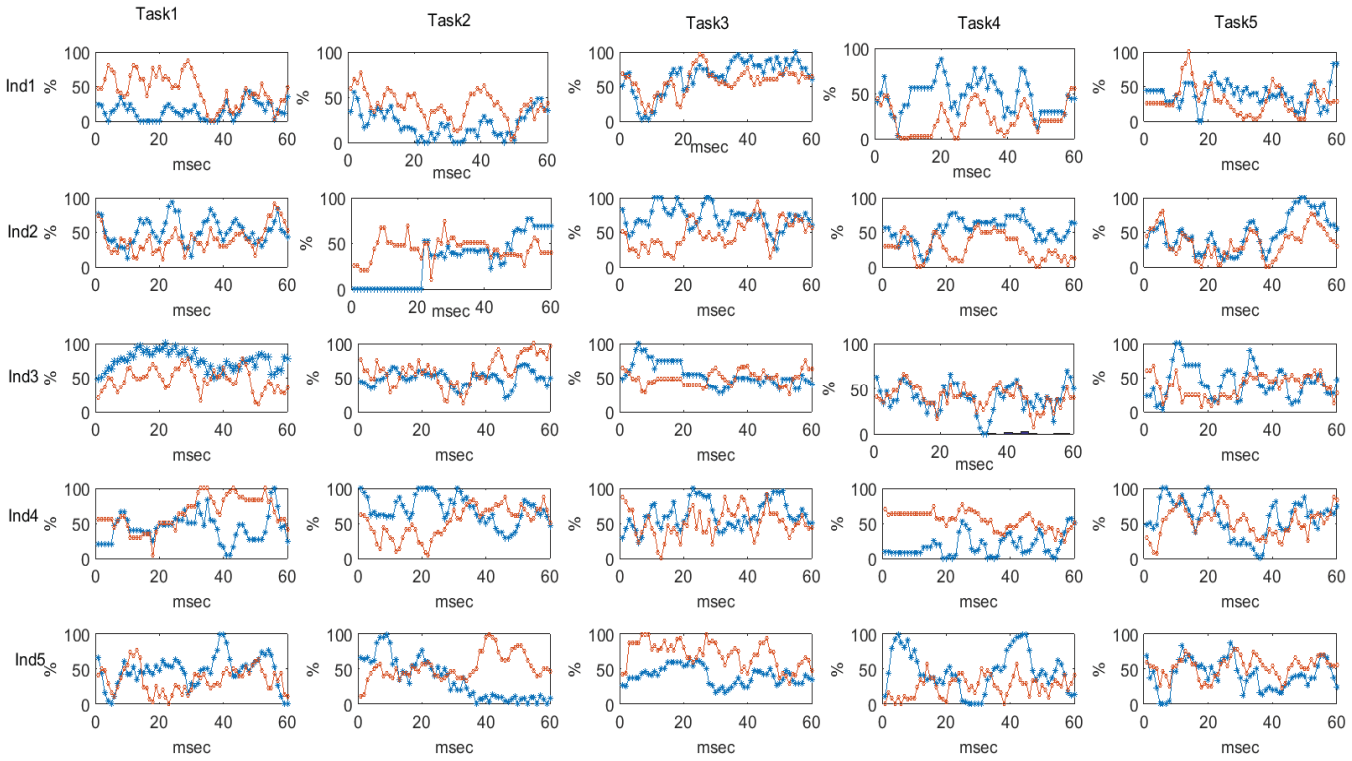

Fig. 1. The level of Attention and Concentration in % by individual and task, considering a time window of 60 msec. The blue line represents the Attention level and the red line the Concentration level.

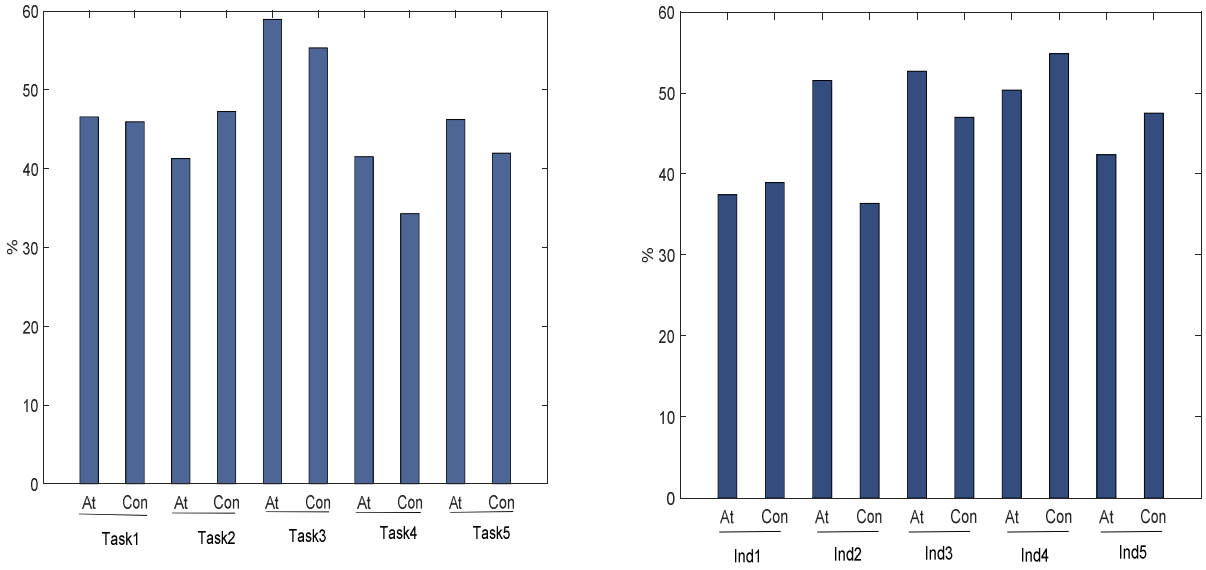

Fig. 2. The average of Attention (At) and Concentration (Con) in % by Task (left graph) and by Individual (right graph). The dataset used is the presented in Figure1.

TABLE 2. PEARSON CORRELATION COEFFICIENT BETWEEN CONCENTRATION AND ATTENTION LEVEL BY TASK AND INDIVIDUAL (** CORRELATION SIGNIFICANT AT 0,01 LEVEL AND * CORRELATION SIGNIFICANT AT 0,05 LEVEL)

	Task1	Task2	Task3	Task4	Task5
Ind1	0,164	**0,48****	**0,623****	**0,370****	0,2
Ind2	**0,407****	**0,875****	-0,073	**0,268***	**0,724****
Ind3	**0,260***	**0,292***	**-0,310***	**0,547****	0,049
Ind4	0,037	**-0,426****	0,12	-0,078	**0,416****
Ind5	0,177	**-0,465****	**0,348****	-0,245	**0,499****

The t-test between the time values of Attention and Concentration between individuals for each task is performed with a significance of 0.05. Statistically comparing the performance of individuals for each task, we can infer certain conclusions that confirm what was described previously, Table 4.

Attention is statistically different among all individuals in Task2, except for Ind2 and Ind5 who have statistically equal values on average. The Concentration is statistically equal between Ind1 and Ind2 and between Ind4 and Ind5. This seems to show that the masculine gender (Ind1 and Ind2) to maintain Concentration (focus) need to be attentive and the feminine gender (Ind4 and Ind5) can stay focused without being aware and can ignore music that does not seem to be of their preference.

In Task 3, Ind2, Ind3 and Ind4 have similar average Concentration levels. Ind2 and Ind5 are always statistically equal in Concentration for all tasks except Task 3. In Task 4 and Task 5, Ind5 presents Attention levels statistically equal to Ind1, Ind2 and Ind3. In addition, Ind2 and Ind5 have statistically equal behaviours of Attention in the isolated tasks.

When performing individual tasks (Task 1, Task 4 and Task 5) there are no significant differences between individuals, which means that the male and female gender have similar levels of Attention and Concentration. However, in parallel tasks, this study brings out musical preferences.

TABLE 3. PEARSON CORRELATION COEFFICIENT BETWEEN TASKS FOR ALL INDIVIDUALS CONSIDERING THE ATTENTION AND CONCENTRATION PARAMETER (** CORRELATION SIGNIFICANT AT 0,01 LEVEL AND * CORRELATION SIGNIFICANT AT 0,05 LEVEL)

	Ind1		Ind2		Ind3		Ind4		Ind5	
	At.	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***
T1-T2	0,103	**-0,430****	0,128	**0,308***	0,238	-0,179	**0,347****	**0,656****	-0,254	**0,265***
T1-T3	-0,047	-0,214	-0,009	**0,286***	0,231	0,133	-0,12	**0,351****	0,048	-0,139
T1-T4	**-0,256***	-0,223	**2,73***	-0,206	-0,099	0,171	-0,083	**-0,437****	0,096	0,116
T1-T5	-0,027	0,04	-0,152	0,194	0,228	**0,269***	-0,216	**-0,419****	0,136	0,237
T2-T3	-0,237	-0,181	**-0,302***	**0,498****	0,055	0,053	-0,201	**0,346****	**0,388****	**-0,380****
T2-T4	**-0,269***	0,019	**-0,331****	0,041	**0,348****	-0,139	-0,121	**-0,617****	0,05	0,229
T2-T5	0,008	**0,501****	**0,436****	0,063	0,126	-0,123	**-0,314***	**-0,429****	0,183	-0,245
T3-T4	0,053	0,159	-0,112	**-0,274***	0,181	-0,004	0,253	-0,196	0,01	-0,171
T3-T5	-0,116	-0,157	**-0,538****	-0,075	0,064	0,149	0,036	**-0,375****	0,24	-0,174
T4-T5	0,124	**-0,415****	-0,246	-0,181	-0,155	-0,14	-0,003	0,162	**-0,536****	0,245

TABLE 4. THE T-TEST-VALUES CONSIDERING THE TIME VALUES OF ATTENTION AND CONCENTRATION BETWEEN A PAIR OF INDIVIDUALS BY TASK

	Task1		Task2		Task3		Task4		Task5	
	At.	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***	***At.***	***Conc.***
I1-I2	3,6e(-17)	**0,27**	0,076	**0,2**	**0,13**	3,19e(-4)	0,04	0,039	0,037	**0,23**
I1-I3	6,9e(-35)	**0,49**	8,1e(-20)	1,6e(-7)	0,036	0,0018	0,04	1,7e(-8)	**0,26**	**0,1**
I1-I4	4,6e(-13)	3,11e(-4)	1,33e(-22)	0,0032	**0,42**	0,031	2,6e(-11)	2,58e(-17)	5,1e(-5)	5,7e(-8)
I1-I5	3,2e(-15)	0,014	1,88e(-4)	3,1e(-4)	1,98e(-8)	0,0013	**0,99**	**0,25**	**0,48**	1,85e(-8)
I2-I3	3,4e(-10)	0,04	7,2e(-6)	4,55e(-5)	6,6e(-8)	**0,47**	1,26e(-5)	1,12e(-5)	**0,29**	**0,57**
I2-I4	0,01	1,04e(-9)	1,0e(-11)	0,016	0,014	**0,27**	1,59e(-18)	1,8e(-13)	0,044	2,7e(-4)
I2-I5	**0,22**	**0,13**	**0,737**	0,0038	1,7e(-19)	1,2e(-6)	**0,18**	**0,34**	**0,13**	8,5e(-4)
I3-I4	4,5e(-15)	3,23e(-5)	2,5e(-10)	0,02	0,039	**0,5**	3,26e(-14)	1,7e(-9)	0,0063	3,44e(-8)
I3-I5	2,9e(-11)	7,08e(-4)	2,26e(-4)	0,027	64e(-10)	3,49e(-10)	**0,07**	2,7e(-7)	**0,54**	8,5e(-4)
I4-I5	**0,3**	1,4e(-12)	6,4e(-14)	**0,8**	1,5e(-12)	4,54e(-6)	1,0e(-7)	1,36e(-16)	9,16e(-4)	**0,62**

IV. Conclusions and Future work

To sum up, after looking at the results we can say that music may have a very important role in influencing the Attention and Concentration state of the brain while performing a mental workload, in this case playing a videogame.

Even though our research has some limitations due to the size of the sample being small to generalize and extract extended results, it is possible to infer some conclusions by these results. There is some gender pattern as Ind1, Ind2 and Ind3 present similar behaviour in certain tasks (boys) and Ind4 and Ind5 also have strong Concentration levels when listening to relaxing music (girls). But in some measures Ind5 behaves in a similar way to Ind2. Ind2 and Ind5 are always statistically similar in terms of Concentration levels in all the tasks except in Task 3. Ind5 (girl) reaches very high levels of Concentration with music (isolated and when performing tasks with it) seeming that music is important to her to focus on, no matter the type of music she listens to. Ind2 (boy) also reaches high levels of Concentration with music except when performing tasks with Relaxing music. So, to focus on performing tasks, a specific type of music (Heavy Metal) helps him, possibly a music of his preference. Ind4 is the individual who stands out with higher levels of Concentration while performing tasks. Ind3 is the individual who stands out with higher levels of Attention when performing tasks. Task 3 (the task consisting in playing the game with Relaxing music) is the task with the highest levels of Attention and Concentration.

In our research we had a limited number of participants and only two types of music. However, it can be very interesting to repeat the experiment on a bigger sample and with other types of music in order to observe their effects on individuals Concentration and Attention level. Everyone has a favorite type of music and it can have a significant effect on the Attention and Concentration levels. Therefore, we consider this research very promising as there is much to do, and it could have applications in several fields. In the near future, we are particularly interested in extending this study to analyse the Attention and Concentration of students when learning to program and study the frequency bands of the EEG signal.

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