EEG Analysis of the Music Effect on Lecture Comprehension

V.A. Díaz de León-Esparza[1], A. M. Martínez-Cervantes[1], A. G. Vargas-Cortés[1], A. E. Olivares-Núñez[1], D.I. Ibarra-Zárate[1] and L. M. Alonso-Valerdi[1]*

[1]Tecnologico de Monterrey, Escuela de Ingeniería y Ciencias, Monterrey, N.L., México
vic.abdiel@gmail.com

Abstract— Human concentration depends on many volatile environmental factors and its quantification has been a recurrent research topic. One way to quantify concentration is to record and analyze electrical activity in the cerebral cortex. Music is one factor that significantly influences concentration, both positively and negatively, so we studied the influence of music on the electrical activity generated by the frontal lobe during lecture comprehension. Sixteen subjects were recruited to carry out a lecture with or without music. Frontal lobe electrical activity was recorded during the readings. After each reading, a brief test was applied to quantify the level of lecture comprehension. Subsequently, cortical electrical signals were processed in two frequency bands: alpha (8-13 Hz) and beta (13-30 Hz). Our results suggest that individuals tend to increase their level of lecture comprehension when listening to their favorite music, reflecting a higher level of attention and better focus during the reading decoding process.

I. Introduction

Commonly, concentration is defined as a state of complete attention during the performance of an activity that demands it. Some formal definitions are the following two: (1) "Basic cognitive process that is required for any activity", and (2) "Human capacity to be aware of the events that occur both outside and inside himself" [1].

There are several factors that negatively affect the effectiveness of a person when performing activities that require concentration, for example: stress, lack of sleep, or fatigue. The aim of this project is to study the effect of music during lecture comprehension and via the analysis of cortical electrical signals recorded through Electroencephalography (EEG).

According to a study conducted by the Pedagogical University of Durango, 86% of students recognize the presence of academic stress [2]. In this study, various symptoms of stress were detected, including concentration problems. The lack of concentration due to stress presented in 89.4% of subjects, with an average intensity of 2.9 on a scale of 1 to 5, as the symptom with the highest incidence rate.

Now, why use music? In [3], it was found that music activates certain areas in the brain that enhance memory and attention level. In addition, music makes learning more effective. This means that music can be harnessed to increase concentration in students, and even in professionals. A previous study [4] showed that background music may become an important distractor which reduced reading comprehension. Nevertheless, the study mentioned only considered two musical genres, and the experiment was carried out in English language which was not the native language of the volunteers involved, and this may have elevated the difficulty of the task. In the present study, the whole process was carried out in the native language of the volunteers. Also, each subject was free to choose the genre of music to listen during the experimentation which is considered an important factor since [5] points out that effects of music on the performance of a task depends on its effects on arousal and mood.

In line with the above evidence, the research question to be answered in this study is: Can music increase the level of concentration during demanding cognitive tasks such as lecture comprehension? As mentioned before, for this investigation the favorite music of participants was chosen since previous investigations [6] have found that it tends to catch attention. Participants were involved in a lecture task where a minimum performance of 70% was taken to consider a sufficient lecture comprehension. In addition, level of neural synchrony was estimated (specifically in alpha and beta bands) to evaluate mental resources involved in the lecture and possibly affected by music. Findings are discussed and compared with previous studies by the end on the manuscript.

II. Methodology

A. Sample

For the study, 16 young adults were recruited, consisting of 8 men and 8 women between 20 and 25 years old. They were informed about the purpose of the study and the experimental procedure during an induction session. See Figure 2. The project was previously approved by the Ethics Committee of the Tecnológico de Monterrey School of Medicine (registration number in the National Bioethics Commission CONBIOETICA-19-CEI-011-20161017 and in the Research Committee 17CI19039003). Once the volunteers agreed to take part in the project, they signed a consent form and followed the experimental procedure described below.

B. Materials

For this study, considering the available resources 4 EEG channels were recorded according to 10/20 International System [7]. These were: AF7, AF8, TP9 and TP10. The channels were referred with respect to the Fpz channel with a sampling frequency of 220Hz. The registration system was the muse headband, developed by the INTERAXON company of Toronto, Canada. See Figure 1.

C. Experimental Procedure

Resting state. In the first stage, EEG signals were recorded while volunteers were seated on a comfortable chair, watching at a fixed point for three minutes.

Lecture comprehension with no music (NM). In the second stage, a lecture comprehension test was carried out. The manuscript titled as "El plan de la NASA para destruir un gran asteroide que se dirige a la Tierra " (607 words) was selected.

Lecture comprehension with music (WM). In the third stage another lecture comprehension test was carried out. At this stage, the manuscript selected was titled "¿Llegó a formular Stephen Hawking una teoría del todo?" (665 words).

Figure 2. Induction session for volunteers who were recruited for the present study. Note that the session was carried out in mostla labs at Tecnológico de Monterrey

Each volunteer was given 4 minutes to complete the exercise. Having completed the lectures, volunteers answered two questionnaires with 6 items each one. On average, they concluded on 4 minutes. At the end of the test, volunteers filled out a survey about their favorite music and the kind of activities they usually do when they listen to it.

D. EEG Signal Analysis

For EEG signal analysis, EEGLAB toolbox [8] was applied, which is programmed in MATLAB and is typically used for the processing of electrophysiological signals.

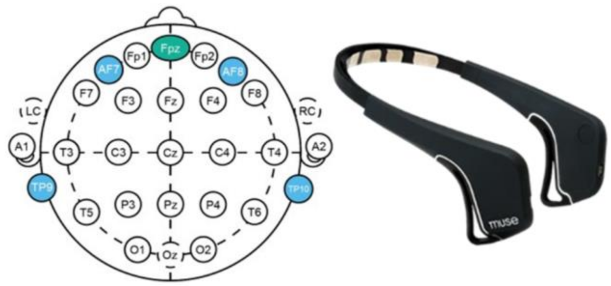

Figure 1. On the left side, the 10/20 system is shown with the measuring electrodes in blue and the reference electrode in green. On the right side, the muse headband is shown (http://www.choosemuse.com/).

The signal processing was as follows. First, signals were filtered within a bandwidth between 0.1 and 30 Hz through an 8th order Butterworth bandpass filter. Then, signals were visually inspected and discontinuities (e.g., abrupt and unexpected movements, pop-up electrodes, or yawns) were manually removed.

Once signals had been preprocessed, they were filtered (design: Butterworth, order: 6, type: IIR) in two narrow bandwidths: (1) alpha (8-13Hz) and (2) beta (13-30Hz). These brain rhythms were estimated since neural networks usually synchronize in alpha during relaxation and under a state of mental inactivity. They are better seen with closed eyes, being much more prominent over occipital lobe. On the other hand, neural networks reflect greater synchronicity in beta band in highly demanding cognitive tasks such as mathematical calculations, tension or concentration over the central and frontal areas [6]. In these two frequency bands, the Power Spectral Density (PSD) was estimated by segmenting the EEG signals into 8 segments with 50% overlap. Every segment was passed through a Hamming window. Having calculated the PSD per volunteer, the grand average of volunteers who achieved a minimum performance of 70% during the lecture test was obtained. On the other hand, that of those who were below 70% was determined apart. This signal processing was applied to each of the 4 EEG channels.

E. Statistical Evaluation

The average PSD of both groups (above 70% and below 70%) were statistically compared using the Wilcoxon ranked test to find a significant difference at 5%. This statistical method was applied since EEG signal are non-linear and dynamic systems.

III. RESULTS

A. Survey

The survey showed the results shown in Figure 5, where it is revealed that volunteers tended to perform their daily activities by listening to music. However, when total and deep concentration is necessary such as lectures, volunteers preferred to avoid it.

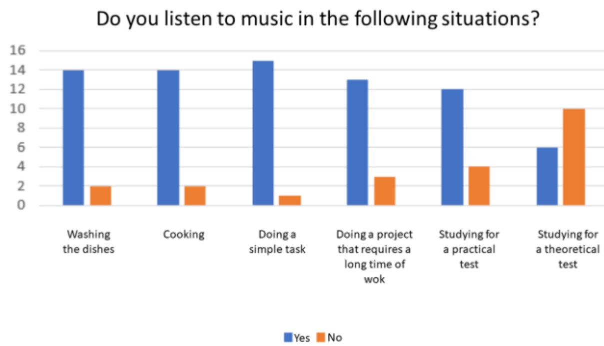

Figure 5. Pre-procedure survey results

B. Lecture Evaluation

Regarding the first test (no music-NM), 50% of volunteers reached a performance equal to or greater than 70%. The average evaluation (μ) was 72.6% with a standard deviation (σ) of 21.3 as shown in Table 1. The results of the second test (with music - WM) indicate that 64% of volunteers reached a performance equal to or greater than 70%. The average performance was 79.7% with a standard deviation of 14.9. Note that the best performance in the test was achieved by the participants who did the lecture WM.

C. PSD

The students who approved the lecture comprehension exam with a minimum grade of 70% were defined as 'approved' in the opposite case were referred to them as 'non-approved'. In Figure 3, the average PSD of all participants during the NM reading test is shown, both for alpha and beta bands in two study cases: (1) participants with performance greater than 70% and (2) participants with performance less than 70%. From the figure, it can be seen that the average PSD of the approved ones was greater than that of the non-approved ones, both for alpha and beta bands. However, there was only a significant difference of p = 2.3191e-21 in alpha band. On the other hand, it can be seen in Table 1, that the PSD with the greatest magnitude was the one estimated in the beta band. In Figure 4 , the average PSD of all participants during WM reading test is shown, both for alpha and beta bands in two case studies: (1) participants with performance greater than 70% and (2) participants with performance less than 70%. From the figure, it can be seen that the average PSD of the approved ones was greater than that of the non-approved ones, both for the alpha band and the beta band. Unlike the NM case, there was a significant difference in both alpha (p = 1.1776e-20) and beta (p = 1.5898e-16).

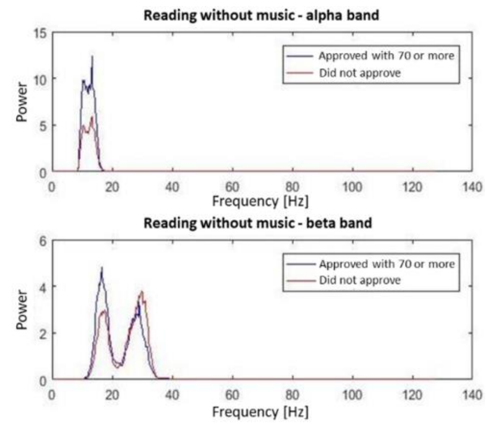

Figure 3. Average PSD in the alpha and beta bands for approved and unapproved volunteers in the reading evaluation without music (NM).

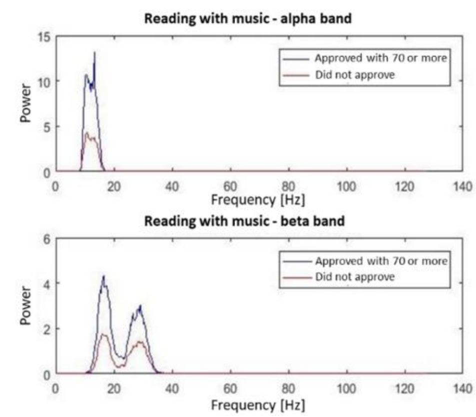

Figure 4. Average PSD in the alpha and beta bands for approved and non-approved subjects in the reading evaluation with music. (WM).

On the other hand, it can be seen in Table 1, that the PSD with the greatest magnitude was the one estimated in the alpha band.

IV. Discussion

Concentration is a process that cannot be only considered neurophysiological, since this activity involves other factors, including a psychological part to be considered. In this study, the objective was to identify whether listening to music favors this process or not, by analyzing the cortical electrical activity generated in the frontal lobe. Hereunder, the results of the study are discussed.

A. Survey

The survey showed that more than 75% of volunteers tended to listen to music during low demanding cognitive tasks. By contrast, 71% of volunteers did not listen to music in high demanding cognitive tasks. However, lecture evaluation showed a different picture.

Table 1. Evaluation of the lecture comprehension

Volunteer		Reading Evaluations			PSDEEG		
	Age (Years)	Evaluation NM	Evaluation WM	Test with better performance	Greater PSD NM	Greater PSD WM	
1	24	100	66.67	NM	Alpha	Beta	
2	23	50	83.33	WM	Beta	Beta	
3	24	83.33	100	WM	Alpha	Alpha	
4	23	100	83.33	NM	Beta	Alpha	
5	21	83.33	83.33	No Difference	Beta	Alpha	
6	24	83.33	100	WM	Beta	Alpha	
7	21	83.33	100	WM	Beta	Alpha	
8	23	50	83.33	WM	Beta	Alpha	
9	22	66.67	66.67	No Difference	Alpha	Alpha	
10	23	66.67	50	NM	Beta	Alpha	
11	23	33.33	66.67	WM	Alpha	Alpha	
12	21	66.67	66.67	No Difference	Beta	Beta	
13	24	50	83.33	WM	Beta	Alpha	
14	23	100	83.33	NM	Alpha	Alpha	
Average (μ)	22.78	72.6	79.76	WM	Beta	Alpha	
Standard Deviation (σ)	1.12	21.29	14.87	NM	Alpha	Beta	**Mode (M)**

B. Reading Evaluation

Half of the volunteers (50%) achieved their best performances during reading activity WM. By contrast, 29% of them did it during the NM reading and the rest (21%) did not show different performances between WM and NM reading.

C. PSD

The results of the PSD analysis showed that volunteers who performed the WM test and who also approved the test reflected greater neuronal synchrony (i.e., the PSD with greater magnitude) in alpha and beta bands, than those who performed the same WM test, but that they did not approve. Another interesting result is that the level of maximum neuronal synchrony (i.e., PSD with greater magnitude) during the NM test was reached in most of the volunteers (64%) in the beta band. By contrast, the maximum neuronal synchrony was reached during the WM test in most of the subjects (71%) in the alpha band.

The results of the study suggest that volunteers did not only achieve better WM lecture comprehension performances, but also showed levels of neuronal synchrony (both in alpha and beta, but mainly in alpha) much higher than those volunteers who did not pass the same test. In addition, during the NM test, even though only one task was done at a time, which was reflected by the trend for the beta band and its similarity between approved and unapproved, the volunteers did not manage to concentrate at the same level as during the WM test. However, the results should be taken with caution since a sample of only 16 volunteers was considered.

V. Conclusion

The present study suggests that individuals tend to increase their level of lecture comprehension when they listen to their favorite music, reflecting a higher level of attention (high alpha synchrony level) and better focus during lecture exercise (level of synchrony in high beta). Taking this EEG data into consideration, music chosen by subjects can be beneficial to enhanced execution of some tasks.

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