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How Does Environmental Noise Impact Collaborative Activities at the Main Library of Tecnologico de Monterrey?*

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Abstract— **Environmental noise is an important social issue that directly affects the efficiency of the students. The aim of this study is to investigate how environmental noise generated in the library affects the performance at learning commons. For this study, the noise of the library was recorded and sixteen students of Tecnologico de Monterrey, were recruited. They were divided into four groups, and two collaborative activities were undertaken with and without noise. In both scenarios, the performance and the physiological reaction of students were investigated. The results showed that the students had a 4% higher performance in a quiet environment than in a noisy one, in the same way, the heart rate increased by 3.48% and the blink rate by 22.91%. Finally, the neural electrical activity was reduced by at least 3%. The findings of the present study suggest that collaborative work is difficult to undertake in noise scenarios such as learning commons, where no appropriated policies are established and followed. Cognitive performance is lower in noisy than in quiet conditions.**

I. INTRODUCTION

A human being first filters sensory input information, and then, an interpretation arises so as to provide an answer. Therefore, perception and cognition go together to create a correct interpretation of the environment. Human auditory system is responsible for the physiological processes of hearing, such as the capture of sound and its transformation into electrical impulses, through the auditory nerves. The importance of sound in the perception and stimulation of cognition is described as the means by which one has direct contact with the environment [1, 2].

Sound is perceived by humans in four basic qualities: intensity, duration, pitch and timbre. When a sound has a fair proportion of the previous qualitative components, they can generate pleasant sounds or, on the contrary, annoying ones. In this latter case, sound becomes noise. Noise is commonly defined as unwanted sound with negative effects on human health and well-being, these effects can be biological, social, psychological, and behavioral [3]. It has been shown that cognitive performance can be affected by noise, resulting in attention deficits, memory deterioration and poor linguistic processing [4].

Along with the generation of digital natives, reduction and openness of both learning and working spaces has become a common practice, particularly at academic libraries and working environments. Unfortunately, commons have become an important environmental noise source. In fact, a qualitative inquiry undertaken in three US Universities revealed that students frequently complain about the noise level in the libraries, and the lack of formal rules regarding noise [5].

Environmental noise in learning commons goes beyond implementation of new library policies. Indeed, it severely affects learning [6, 7]. Noise as a learning problem has been widely studied and it is well known that noise pollution limits the amount and quality of information collected from working environments, affecting perception, cognition, and unquestionably, learning [8].

The objective of the present study is, therefore, to investigate the effect of environmental noise on student performance while doing collaborative activities at noisy environment such as learning commons of the main library of Tecnologico de Monterrey in Monterrey, Nuevo Leon, Mexico. The recently opened library is recognized by the open auditorium and the learning commons [9], however, despite that institutional policies establish that library learning commons are a place dedicated to educational and learning purposes, they are actually used to recreational and social activities very far from the real purpose. The noise pollution caused by all those activities are affecting students actively involved into collaborative projects. To investigate how environmental noise in library commons is affecting undergraduate learning, this study aims to compare the performance and the physiological reaction of students when doing collaborative tasks (solving a puzzle of 300 pieces) under quiet and noisy conditions. The performance and the physiological reaction of students were investigated by (1) a summative evaluation based on the level of puzzle completeness, and (2) the electrophysiological monitoring of heart and blink rate, and neural electrical activity.

The EEG and ECG signals of all participants can be accessed for the experimental procedure in [10].

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II. METHODS

A. Sample

The present study was previously approved by the Ethics Committee of Tecnologico de Monterrey. For the study, sixteen (nine males and seven females) undergraduate students were voluntarily recruited. They were between 19 and 25 years old. Exclusion criteria were: (1) clinical history concerning neurological and/or psychiatric diseases, (2) clinical history concerning pharmaceutical drug use that affect the central nervous system, (3) previous consumption of psychotropic drugs, (4) failure of a psychometric test of cognition [11], (5) consumption of coffee prior to the experiment, and (6) prolonged fasting (12 hour or more).

B. Experimental Design

To define the experimental setup and establish the experiment procedure, three preliminary steps were followed. These were: (1) to identify the most frequent activities done at the library, (2) to record the environmental noise at the main library of Tecnologico de Monterrey, and (3) to measure the equivalent noise level (L_{eq}) in learning commons. To identify the frequent activities, a survey was applied to 60 students at the library so as to identify the most frequent activities done by students. Seven activities were included in the poll. These were: (1) individual work, (2) collaborative work, (3) relaxing, (4) eating, (5) listening to music, (6) reading, and (7) socialization. It was found that majority of students attended to the library for undertaking collaborative activities. On this evidence, solving a puzzle was selected as experimental task since it requires teamwork, and cognitive processes such as attention, memory and perception. To record the environmental noise at library, the times in library were identified (these were from 15.30 till 18.30hrs.), and then, L_{eq} was measured by using a sound level meter, B&K type 2270. This sonometer was calibrated with a sound calibrator type 4231. The L_{eq} 78 dBA. At the same time, background noise was recorded by a Tascam DR-05 professional audio recorder, with sampling frequency of 44.1 kHz and a frequency response from 20 Hz to 20 kHz, also previously calibrated. The most representative environmental noise in the library has a main frequency in the spectrum around 1 kHz, due to the voices in background noise.

C. Experimental Procedure

Prior to the experiment, the practical method for grading the cognitive state proposed in [11] was applied to evaluate the eligibility of volunteers. The evaluation had 35 items and the minimum approbatory grade was 30/35. Five cognitive areas were assessed: (1) orientation, (2) fixation, (3) concentration and calculus, (4) memory, and (5) language.

Once volunteers were selected and agreed to take part in the study, they were divided into four groups of four members each. Then, they were seated in a comfortable chair to mount the necessary electrodes for recording electrophysiology activity of neurons, heart and eyes, namely, Electroencephalophy (EEG), Electrocardiography (ECG), and Blink Rate (BR). After the experimental setup was ready, electrophysiological signals were recorded at rest for three minutes, and then, each team was given five minutes to establish its teamwork strategy. Finally, the team proceeded to solve two very similar 300-piece puzzles for ten minutes each. The first one was solved under quiet conditions, and the second one was solved under noisy conditions, using a BOSE full-range loudspeakers to recreate the ambient noise recorded in the library. For this last condition, the environmental noise recorded in the library learning commons (i.e., L_{eq} of 78 dBA) was played along ten minutes.

D. Recording and Analysis of Electrophysiological Signals

Heart Rate: ECG signals. In this study, with the BIOPAC system, the electrical activity of the heart was recorded at 200 Hz within a bandwidth from 0.1 to 100 Hz using the Einthoven's triangle lead I. For analysis, ECG signals were band-pass filtered between 0.5 and 50 Hz applying a 6th order Butterworth IIR filter. Thereafter, QRS complexes were detected and the distance between them were estimated (NN intervals). Finally, NN intervals were averaged to calculated Heart Rate (HR) and converted into beats per minute (bpm). For signal processing, MATLAB coding and EEGLab open-source toolbox were used [12].

Relative Band Power: EEG Signals. The recording sites of the MUSE headband were mounted according to the 10/20 International System, and four EEG channels were recorded at 220 Hz within a bandwidth from 0.1 to 100 Hz. The EEG channels were: AF7, AF8, TP7 and TP8, but only channels AF7 and AF8 were used. These channels were chosen since frontal lobe is associated with complex cognitive processes known as executive functions, which make possible to choose, plan and make voluntary and conscious decisions [13]. The EEG oscillations to be analyzed were alpha and beta bands. On one hand, alpha rhythms dominate at relaxation, consciousness, attention and working memory. On the other hand, beta rhythms dominate at motor behavior and active thinking [14].

AF7 and AF8 were processed as follows. First, signals were filtered through a Butterworth IIR filter of 6th order at the following bandwidths: Alpha (8-13 Hz) and beta (13-30 Hz). Second, the absolute mean power was calculated in both bands. Third, relative power was estimated by dividing absolute alpha and beta band powers [2]. Similar to ECG analysis, MATLAB coding and EEGLab open-source toolbox were used for signal processing.

Blink Rate: Blinks are not only necessary to lubricate the eye, but they also reflect cognitive processes. In fact, majority of blinks are due to cognition, rather than physiological necessity. In general, an individual blink from 15 to 20 times per minute, but only a pair of them are physiologically necessary [15]. On this basis, blink rate (BR) was monitored during experimentation via the binary channel of MUSE headband that detects blink events.

E. Statistical Evaluation

For the statistical evaluation, the analysis of variance (ANOVA) was applied to determine if there were statistically significant differences ($p < 0.05$) between the two groups [16]: (1) puzzle activity with noise, and (2) puzzle activity without noise. On the basis of electrophysiological changes (HR, alpha/beta band power, and BR) and performance (number of puzzle pieces that were assembled), statistical difference was determined.

III. Results

A. Teamwork Performance

Fig. 1 shows the number of puzzle pieces that were assembled per team under two conditions: quiet and noisy. All of the four teams had a better performance when assembling the puzzle under quiet conditions, as it was expected. In Fig. 1, it can be seen a difference of 3.34% on average between working with and without noise. Both number of pieces ($p = 0.0355$) and level of completeness ($p = 0.0353$) were significantly different between the two conditions.

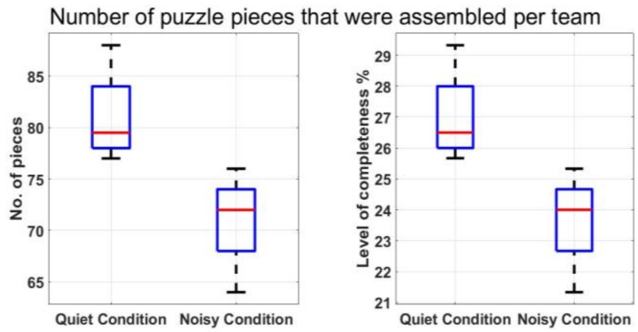

Figure 1. Number of puzzle pieces that were assembled per team under two conditions: without and with environmental noise.

B. Heart Rate (HR)

Fig. 2 shows the HR distribution of each volunteer in three conditions: (1) at rest, (2) solving the puzzle without noise, and (3) solving the puzzle with noise (L_{eq} 78 dBA). Median HR of all the 16 participants was respectively in the three conditions 70.37, 76.86 and 79.31 bpm. HR of volunteers among the three conditions were statistically different ($p = 0.0072$).

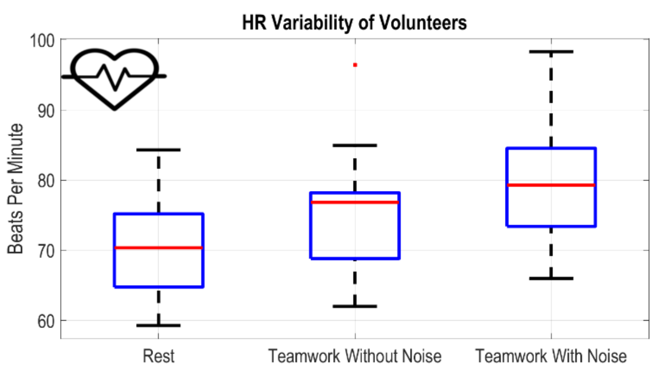

Figure 2. HR of 16 volunteers in bpm under three conditions: rest, and solving the puzzle without and with environmental noise.

C. Blink Rate (BR))

Fig. 3 shows the number of blinks per minute of the 16 volunteers in the three aforementioned conditions. From Fig. 3, it can be seen that the lowest BR was reached when volunteers were solving the puzzle in a quiet environment. A significant difference among the three conditions was found ($p<0.001$), and the median values were: 24 blinks at rest, 7 blinks working in quiet conditions, and 12.5 blinks working in noisy conditions.

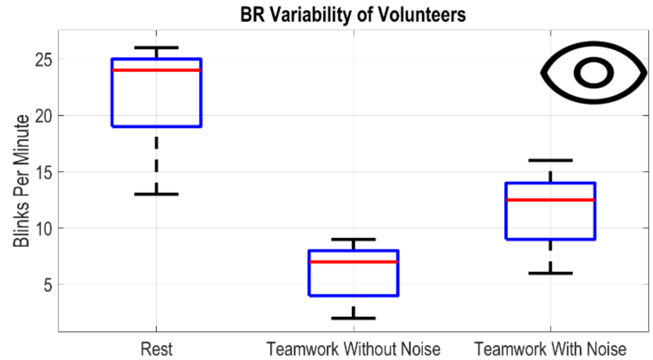

Figure 3. Blinks per minute of 16 volunteers under three conditions: rest and solving the puzzle without and with environmental noise.

D. Relative Band Power: Alpha/Beta

Fig. 4 shows the relative band power of the 16 volunteers in the three previously mentioned conditions. From Fig. 4, it can be seen that relative band power is higher at rest than when solving the puzzle either in quiet or in noisy conditions. In addition, a relative band power is slightly higher under noisy than quiet conditions. Statistically, there was significant difference among the three conditions in both EEG channels ($p = 0.028$).

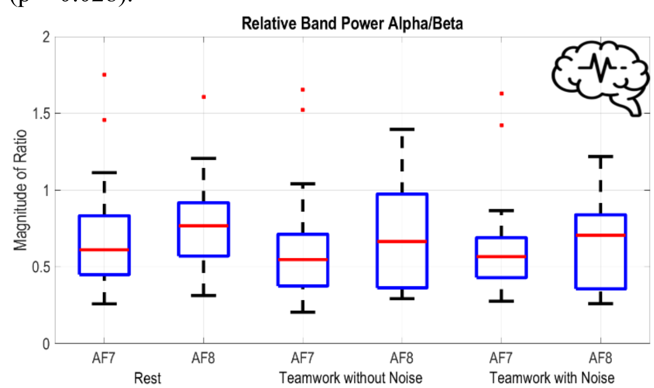

Figure 4. Relative band power over frontal lobe (AF7 and AF8) of 16 volunteers under three conditions: rest and solving the puzzle without and with environmental noise.

IV. Discussion

It is well established that environmental noise significantly impacts human wellbeing, including audition, cognition, emotions, and physiological functions [17]. As a result, quality of life is reduced, and daily activities are affected. Over the past few years, reduction and openness of studying/working spaces have promoted the internal environmental noise, altering human behavior and performance, either at academic institutions or at work.

The performance of four student teams at the puzzles in 10 minutes was better in quiet than in noisy conditions when the L_{eq} was at least 78 dBA. On average, teams working without noise completed the puzzle at 27%, while they reached 23% when working with noise. This result is in accordance with previous studies that have demonstrated that environmental noise in the library affects student performance at academic institutions [7, 8]. However, the effect of environmental noise generated in the library on cognitive performance of students has not been physiologically measured up to now.

In this study, the median HR increased from 70.37 bpm at rest to 76.86 bpm at working in quiet conditions, and it reached 79.31 bpm when working in noisy conditions. The first HR increment (ΔHR = 6.49 bpm) was possibly due to the mental effort demanded at solving the puzzle [18]. The second HR increment (ΔHR = 8.94 bpm) was more likely associated with the noise effect on the cardiovascular system [1]. Regarding BR, the median BR diminished from 24 blinks per minute at rest to only 7 when solving the puzzle (ΔBR = 17 blinks per minute). Interestingly, the median BR only decreased from 24 to 12.5 blinks per minute when solving the puzzle in noisy conditions (ΔBR = 5.5 blinks per minute). The considerably BR diminution when solving the puzzle in quiet conditions is likely owing to the attention demand. Although attention was also required when solving the puzzle in noisy condition, BR was higher than in quiet conditions since BR increases in the following three situations strongly related to noise: (1) stress, (2) negative emotions, and (3) frustration when a task cannot be completed [19].

Finally, the median ratio alpha/beta diminished as well from rest to teamwork situations. However, the alpha/beta diminution was slightly greater when working in quiet conditions (ΔAF7 = 0.063, ΔAF8 = 0.102) than in noisy ones (ΔAF7 = 0.045, ΔAF8 = 0.062), in comparison with resting state. Band power reflects the level of synchrony of EEG signals. A greater power implies a higher level of synchrony. Furthermore, the frequency at which signals oscillate reflect the level of awareness and concentration. A higher frequency oscillation implies a higher level of awareness and concertation. Overall, delta (0-4 Hz) is associated with deep sleep, theta with sleep (4-8 Hz), alpha with relaxation and general attention (8-13 Hz), beta with active thinking (13-30 Hz), and gamma with perception (30-100Hz) [20, 21]. On this basis, it is hypothesized that beta band dominated over alpha band when solving the puzzle in both conditions since active thinking was required in comparison to resting state. Although ratios are very similar in both conditions, they were slightly lower in the quiet condition than in the noisy one since some mental resources were only allocated to solve the puzzle. However, this was not achievable in the noisy condition since attentional resources (alpha band power) were probably redirected towards environmental noise.

V. Conclusion

In conclusion, the findings of the present study suggest that collaborative work is difficult to undertake in learning commons, when no appropriated policies are established and followed. As a result, cognitive performance when doing the task at hand is lower than in quiet conditions. Indeed, environmental noise in learning commons could not only affect performance, but it might also provoke aggressive behaviors in students. Recent findings demonstrate that high noise levels (between 70 and 90 dBA) did not only psycho-physiologically affect employees, but it also increased readiness to react aggressively to everyday life situations [22].

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