Attention and concentration in normal and deaf gamers

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***Abstract*—In this research the performance of individuals with normal hearing and impaired hearing while playing a computer game was evaluated. The aim was to study and understand if impaired hearing gamers are at disadvantage when playing games without being able to hear the music. Three levels (attention, concentration and blinking) were measured to compare and understand how sound can influence players' attention and concentration performance. The data was recorded using Mindwave equipment during the game Outlast considering two scenarios: game with sound and game without sound. The results show that hearing impaired individuals have the same standard of attention and level of concentration as individuals with normal hearing when there is sound in the game. In the case of the blinking level, this is quite different between the scenarios and the analyzed groups. For this particular study the results suggest that sound is not an important level in the attention and concentration performance of impaired hearing players. Although much work still needs to be done, there is evidence of a relation between the attention and the concentration levels between normal hearing and impaired hearing individuals in the presence and absence of sound.**

Keywords—EEG, Mindwave, Impaired Hearing, Attention, Concentration, Blinking, BCI.

I. Introduction

Impaired hearing is a problem that affects millions of people around the world and manifests itself at different intensities and with many different causes. This disability negatively affects different aspects of people's social life. This is important in tasks in which sound is the focus, particularly in cases of interaction with technology when sound is an essential way to communicate, such as in many computer games. In literature, some points are discussed related to the accessibility in computer games or video games [1]. There is also research on the relationship between hearing impairment and musical perception. Normal hearing people focus on the sound itself when they listen to music (listening to music) while also paying attention to the source or situation of sound around them (daily listening) [2]. This fact influences levels of concentration and attention and can be important in understanding the type of music that can induce higher levels of attention and concentration, improving the performance in the game. In the case of deaf individuals, it has been shown in literature that they have better visual skills, with significant differences in visual cognition [3]. In [4] it is shown that impaired hearing participants reacted to a peripheral stimulus with an abrupt onset more rapidly than hearing participants did. Using Kinect, in [5] it is reported that deaf adults were better at detecting a moving light in the periphery but showed no such enhancement in a static task.

Studies on the relationship between hearing loss and listening to music have been performed within several areas. In music therapy, the positive effects of musical interventions on children with hearing loss have been described [6]. Much of the recent research on music with hearing loss has focused on the emerging technologies related to cochlear implants, while some studies look particularly at hearing loss with just hearing aids, such as in the description of how people with hearing aids listen to music from an audiological perspective [7]. Music perception by people with hearing loss has also been explored from various perspectives: which music elements to use in an experiment, ways to propose music, benefits of cochlear implants and hearing aids, and the age and impairment history of participants [8].

Some studies were conducted to understand whether a combination of tactile and visual information could be used to enhance the experience of music by the hearing-impaired [9]. The level of attention in impaired hearing individuals has been the object of numerous studies in literature. In [10] attentional patterns are explored associated to positive and negative emotions during sports competition, and athletes' perceptions of the consequences of these attentional changes for concentration and performance. In [11] the aspects of language development that require sustained attention to speech and the aspects that can be accomplished through passive hearing are discussed. In [12] the effect of auditory attention on various pupils response levels was investigated. The results concluded that hearing loss causes an overall decrease in performance but doesn't necessarily have an effect on higher level processes such as attention. Studies with children are common in this area to investigate levels of attention and concentration on tasks. In [3] it is demonstrated that impaired hearing and children without hearing impairments did not differ in measures of sustained attention. However, hearing impaired children were more distracted by irrelevant task information in their

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peripheral visual field, thus presenting lower levels of concentration.

In this paper, we describe an experiment using a computer game in which participants had sound in the game and then no sound. The purpose of the experiment was to determine whether there are any di erences in how impaired hearing people and normal hearing people maintain the attention and concentration levels in the two situations. A system based on EEG collection levels, Mindwave, is used during the game to save the information related to attention, concentration and eye blinking levels.

This paper is organized as follows: section 2 describes the experimental procedure, namely the data acquisition, the game, the testing procedure, the methodology and parameters evaluated, section 3 presents the results and its discussion. In the last section some conclusions are provided.

II. Motivations

A new but emergent field for EEG is BCI, brain computer interfaces. Nowadays, we know in more detail which brain areas are active when we recognize stimuli, when prepare and execute movements of the body or learn and memorize things. This gives rise to very robust EEG applications to direct devices using brain activity. In [13] it was proposed a neurofeedback game where the player uses his attention to control the game and to win points. Some studies such as [3], [14] uses the Mindwave device to study the attention parameter and its influence during the learning process. So, in this study we intend to understand how a BCI could facilitate simple cognitive recognition of attention and concentration levels, considering two populations: deaf people and normal hearing people.

The easy access of Mindwave devices opens a new area of researching fields not only in gaming and disable people but also to understand the cognitive behavior of human beings [15], [16]. In this particular study Mindwave, can provide useful feedback for computer games designers, namely, in the choice of sounds, colors or images. In addition, it will be useful to analyse the games' greater focus moments and also the moments of disinterest, thus allowing strategies to make the game more attractive, regardless of the population. In this particular study, we intend to show how a BCI can be useful in game design for deaf people. This paper also aims to answer the research questions about how the music influences the attention and concentration in computer games and understand if there is a relationship between the blinking level and its influence on attention and concentration levels, in the presence or absence of sound.

III. Experimental Procedure

A. Data Acquisition

Mindwave is a simple and affordable device, consisting of two electrodes, one for EEG dataset records (Fp1 channel) and another electrode for reference signals (the ear clip) and a power switch [17]. Sample rates as high as 512 Hz delivered raw signals in the alpha, beta, delta, gamma, and theta bands. The mindwave EEG sensor processes the brainwave into digital signal and uses the eSense algorithm to compute user's engaging attention and concentration. The eyes blinking level is also recorded. The applications for this device are limited by the available channels for the analysis. However, this device has many important features such as, being non-invasive, since one of its electrodes is located on the forehead and the other is placed on the lobe of one ear. In addition, it has no wires and connects via Bluetooth to mobile devices. The electrode on the forehead is capable of picking up the ambient noise generated by human muscles, computers, and other electrical devices. The fact that it is located in this place, avoids disturbances caused by hair, coupled with the fact that it is in the same place as the frontal cortex, where the cognitive signals linked to consciousness develop. The reference electrode filters the electrical noise. One advantage that this device has is that it does not require any type of solution to moisten the electrodes, which could cause discomfort for users. The applications developed for this device were made for users to interact with their state of attention or concentration, making it quite simple to use. There are a lot of games to enjoy with Mindwave, which requires only a high state of attention to be achieved, making it a good mental exercise to improve this ability. In this experiment three parameters were recorded during the tasks: attention, concentration and blinking levels.

B. The game

Outlast is a first-person survival horror game developed by Red Barrels. It revolves around an investigative journalist, Miles Upshur, who decides to investigate Mount Massive Asylum, a psychiatric hospital in the mountains of Lake County, Colorado. From a tip given by an anonymous source, Miles Upshur breaks in the psychiatric hospital and tries to uncover its secrets, but what he discovers goes much deeper than that and he has to fight for his survival while he tries to leave Mount Massive Asylum [18]. Outlast has simple and objective menus. The game commands are basic and can be used with mouse and keyboard or with a gamepad. In this study a mouse and a keyboard were used to play the game.

C. Testing Procedure and dataset

To evaluate the impact of sound in the 'Outlast' horror game we used a specialized laboratory to test the individuals attention and concentration performance during 15 minutes of play time. Fifteen individuals participated in this study: ten individuals without hearing problems and five deaf individuals. The age of individuals ranged between 18 and 20 years old with an average age of 19 and all individuals are of the male gender. The group of individuals without hearing problems was divided into two subgroups and two tests were performed: one with the sound of the game (five individuals) and the other without sound (five individuals). For deaf individuals, we performed only one test due to their hearing problems. So, the data was divided into three groups as follows:

- Normal Hearing Sound (NH_sound) - Individuals without hearing problems and using sound during the game
- Normal Hearing (NH) - Individuals without hearing problems and no sound in the game
- Impaired Hearing (IH) – Deaf Individuals

In the beginning, we made a survey where we asked some questions to the individuals such as: Do you like video games in general?; Do you like or do you usually play video games in the horror genre?; Do you usually stress?; Do you think the sounds of video games influences stress and attention? The answers were quite similar. Most of them played video games (fourteen individuals), all liked horror games (fifteen individuals), they didn't stress most of the time (ten individuals) and all of them thought the sounds from the video games influenced stress and attention.

D. Parameters evaluated and methodology

The EEG signal can be analyzed in frequency and divided into the following five wavebands: delta, theta, alpha, beta and gamma. In the literature different brain wave oscillations related with different frequencies are described as being associated with some meditation and attention levels. Beta and gamma waves together have been associated with attention, perception, and cognition [2] and alpha waves correspond to meditation levels in the brain activity [2]. In this work the Attention and the Meditation measure described on eSense with a scale of 1 to 100, is used.

The meditation measure is associated to decrease inactivity by the active mental processes in the brain and the attention measure specifies the strength of a user's level of mental "attention" or "focus", which occurs during extreme concentration and mental activity. The eSense Attention meter indicates the intensity of a user's level of mental focus or attention to determine the levels of concentration. eSense Meditation meter is related to the active mental processes in the brain and indicates the intensity of a user's level of mental calmness or relaxation. Table 1 describes the eSense meter values:

TABLE 1. DESCRIPTIONS OF THE ESENSE METER VALUES.

Value	*Description*
[1 20]	'strongly lowered' levels
]20 40]	'reduced'
]40 60]	'neutral' / 'baseline' levels
]60 80]	'slightly elevated' /higher than normal levels
]80 100]	'elevated'/ 'heightened' levels

Attention and Meditation values ranging from 1 to 100, at a sampling rate of 1 Hz. These values are determined via proprietary algorithms. Values between 40 and 60 are considered 'neutral' or baseline, values between 60 and 80 mean slightly elevated eSense levels, and values between 80 to 100 refer to strongly elevated attention/meditation levels. Values below 40 are interpreted as (slightly/strongly) lowered levels. A zero eSense value means that the signal cannot be calculated reliably due to background noise. The blink is also recorded as an integer value between 0-255, indicating the blink strength. For each second the attention and meditation level were recorded and also the blinking level. Briefly the information included in the dataset is:

1) id is id of the record in SQLite database table on the device
2) type represents type of the signal (4 – attention, 5 – meditation, 22 – blink strength)
3) level represents attention level (from 0 to 100), meditation level (from 0 to 100) or blink strength (always positive integer value between 0-255)
4) milliseconds represents time in milliseconds.

IV. RESULTS AND ANALYSIS

This study explored attentional patterns associated to the sound in normal hearing people and impaired hearing people and the relation between attention and concentration and eye blinking.

Figure 1 and 2 present the levels of attention and concentration in normal hearing and deaf people during the game session. The sound is used as a criterion to understand its influence and if it is adamant to maintain the attention and concentration levels. Normal hearing people playing the game with sound had higher levels of concentration than when playing the game without sound. The level of concentration is similar with the impaired hearing individuals (around 60%). We can see from the graph of Fig. 2 that the sound positively influences the levels of concentration. In the case of the attention level, the same does not occur. In this case, the sound negatively influences the concentration performance levels leading to lower levels. It is noteworthy that the level of attention between people with normal hearing in the presence of sound and hearing impaired is similar.

In addition to the attention and concentration levels, the blinking level was used as a way of perceiving its relation with the sound and with the other levels studied. By the analysis of Fig. 3 and 4, it is possible to identify a strong relation between the sound and the level of blinking. It should be noted that the impaired hearing individuals presented the lowest levels of blinking. In the case of normal hearing individuals, the sound increases significantly the level of blinking, but there is still a high level of blinking in the case of the listeners playing without sound.

Figure 4 shows the percentage of blinking during 3 seconds. The average of blinking level for each group in windows of 20 msec with an overlap of 5 msec is computed. It is verified that the group of normal hearing with sound have always high levels of blinking in each window considered. In addition, the boxplot shows that the group of normal hearing sound presents greater dispersion of values, compared to the other two groups.

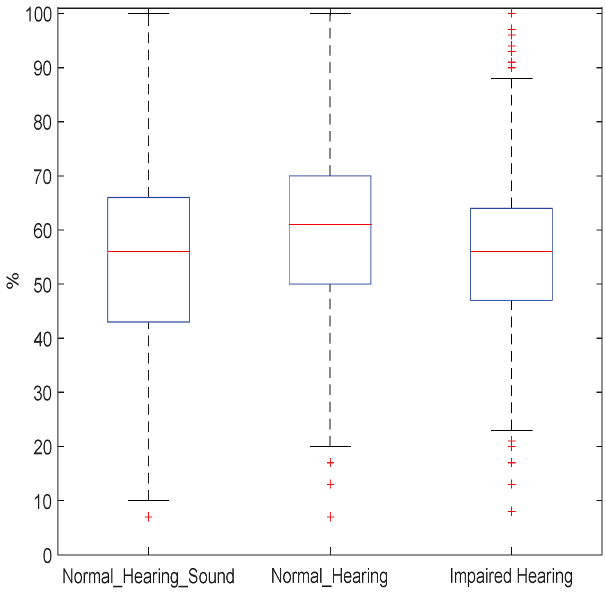

Fig. 1. Boxplots of attention levels considering three different samples: Normal Hearing Sound, Normal Hearing and Impaired Hearing.

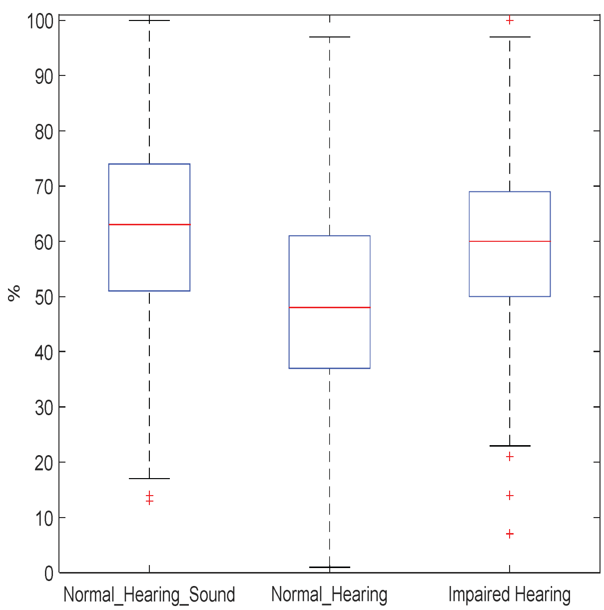

Fig. 2. Boxplots of concentration levels considering three different samples: Normal Hearing Sound, Normal Hearing and Impaired Hearing.

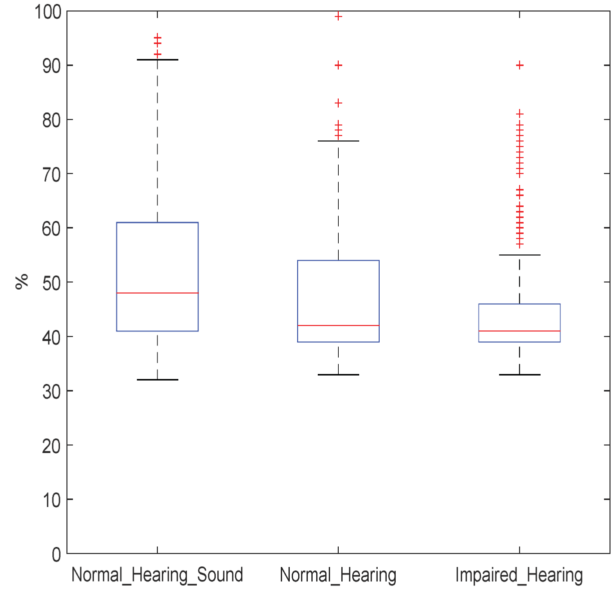

Fig. 3. Boxplots of blinking levels considering three different samples: Normal Hearing Sound, Normal Hearing and Impaired Hearing.

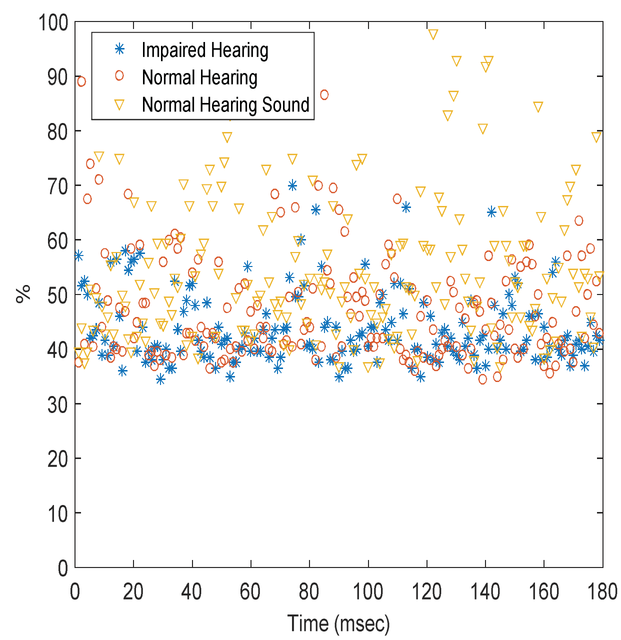

Fig. 4. The average of blink level in windows of 20 sec with an overlap of 5 sec

By the results it is possible to see that the attention and meditation are influenced by blinking. The presence of sound increases the blinking levels. To better understand the levels of attention and concentration a statistical analysis was performed. The t-student statistical test considering a 95% confidence interval was applied to the 3 sets of data (normal hearing with sound and impaired hearing) to understand if the levels of attention, concentration and blinking are statistically different.

In Table 2 the p-values associated to H0 are presented, where the hypothesis testing is:

$$H0: \mu1=\mu2,$$

where,
$\mu1$ – mean of one group
$\mu2$ - mean of another group
and p-values can be interpreted as

1. $p > 0.05$ – means that H0 is accepted
2. $p < 0.05$ – means that H0 is rejected

It is possible to see from the results that there are no significant differences between normal hearing people with sound and impaired hearing in attention and concentration levels.

TABLE 2. T-STUDENT VALUES BETWEEN THE SAMPLES CONSIDERED IN THIS STUDY (NH – NORMAL HEARING; NH_S- NORMAL HEARING SOUND AND IH –IMPAIRED HEARING) FOR EACH LEVEL (ATTENTION, CONCENTRATION AND BLINK).

	Attention		**Concentration**		**Blink**	
	NH	***IH***	***NH***	***IH***	***NH***	***IH***
NH_S	1,50E-07	**2,80E-01**	1,40E-39	**2,50E-01**	2,50E-08	5,60E-20
NH		1,85E-05		6,00E-36		6,70E-05

As for the level of blinking, it is statistically different, as we have seen previously.

V. CONCLUSIONS

The attention and concentration levels and their variation patterns measured during the computer game were useful to understand how the sound can influence the hearing and impaired hearing gamers.

By the collected results we can conclude that the sound influences the attention and concentration levels in normal hearing individuals. In this case, the sound increases the concentration levels and decreases the attention level, which means that, the focus is maintained. The results suggest that the attention and concentration levels between the impaired hearing individuals and the normal hearing individuals when playing game with sound is similar. However, the blinking level differences is evident and discrepant between the three groups analyzed. By the results it is possible to verify that sound induces high levels of blinking. Note that in the case of normal hearing individuals without sound the level of blinking is substantially higher than impaired hearing individuals.

With this paper we can conclude that the integrated information from the EEG signals and variations of attention and concentration levels can provide useful feedback for the game designers, namely in accessibility questions. Furthermore, for the impaired hearing gamers, this system can also be useful to help achieve higher attention and concentration levels and scores in the game. The attention and concentration levels and their variation patterns measured during the computer game by the device were useful to understand how the sound can influence the hearing and impaired hearing gamers.

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REFERENCES

[1] D. Buckley, C. Codina, P. Bhardwaj, and O. Pascalis, "Action video game players and deaf observers have larger Goldmann visual fields," *Vision Res.*, vol. 50, no. 5, pp. 548–556, Mar. 2010.

[2] N.-H. Liu, C.-Y. Chiang, and H.-C. Chu, "Recognizing the degree of human attention using EEG signals from mobile sensors.," *Sensors (Basel).*, vol. 13, no. 8, pp. 10273–86, Aug. 2013.

[3] D. Bavelier, M. W. G. Dye, and P. C. Hauser, "Do deaf individuals see better?," *Trends Cogn. Sci.*, vol. 10, no. 11, pp. 512–518, Nov. 2006.

[4] W. Hong Lore and S. Song, "Central and peripheral visual processing in hearing and nonhearing individuals," *Bull. Psychon. Soc.*, vol. 29, no. 5, pp. 437–440, May 1991.

[5] C. Stevens and H. Neville, "Neuroplasticity as a Double-edged Sword: Deaf Enhancements and Dyslexic Deficits in Motion Processing," *J. Cogn. Neurosci.*, vol. 18, no. 5, pp. 701–714, May 2006.

[6] K. Gfeller, V. Driscoll, M. Kenworthy, and T. Van Voorst, "Music Therapy for Preschool Cochlear Implant Recipients.," *Music Ther. Perspect.*, vol. 29, no. 1, pp. 39–49, Jun. 2011.

[7] A. T. Roy, P. Jiradejvong, C. Carver, and C. J. Limb, "Assessment of Sound Quality Perception in Cochlear Implant Users During Music Listening," *Otol. Neurotol.*, vol. 33, no. 3, pp. 319–327, Apr. 2012.

[8] K. Hansen and R. Hiraga, "The Effects of Musical Experience and Hearing Loss on Solving an Audio-Based Gaming Task," *Appl. Sci.*, vol. 7, no. 12, p. 1278, Dec. 2017.

[9] S. Nanayakkara, E. Taylor, L. Wyse, and S. H. Ong, "An enhanced musical experience for the deaf," in *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*, 2009, p. 337.

[10] R. L. Vast, R. L. Young, and P. R. Thomas, "Emotions in sport: Perceived effects on attention, concentration, and performance," *Aust. Psychol.*, vol. 45, no. 2, pp. 132–140, Jun. 2010.

[11] D. M. Houston and T. R. Bergeson, "Hearing versus Listening: Attention to Speech and Its Role in Language Acquisition in Deaf Infants with Cochlear Implants.," *Lingua.*, vol. 139, pp. 10–25, Jan. 2014.

[12] Koelewijn, N. J. Versfeld, and S. E. Kramer, "Effects of attention on the speech reception threshold and pupil response of people with impaired and normal hearing," *Hear. Res.*, vol. 354, pp. 56–63, Oct. 2017.

[13] A. P. Vinod and C. Guan, "Design of an online EEG based neurofeedback game for enhancing attention and memory," *IEEE Eng. Med. Biol. Soc.*, 2013.

[14] G. U. Navalyal and R. D. Gavas, “A dynamic attention assessment and enhancement tool using computer graphics,” *Human-centric Comput. Inf. Sci.*, vol. 4, no. 1, p. 11, Dec. 2014.

[15] A. Sezer, Y. İnel, A. Ç. Seçkin, and U. Uluçınar, “The Relationship between Attention Levels and Class Participation of First-Year Students in Classroom Teaching Departments,” *Int. J. Instr.*, vol. 10, no. 2, p. 55, 2017.

[16] A. Sholahuddin, *Learning Concentration via Brainwave Using Mindwave*.

[17] Neurosky Mindwave User Guide, “Neurosky Mindwave User Guide,” 2018.

[18] OUTLAST, “https://adegamesinformation.wordpress.com/2015/02/26/outlast/,” 2018.