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Evaluation of Cognitive Benefits among Differently Abled Subjects with Video Game as Intervention

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***Abstract*—**In this study, the potential benefits of playing action video game among congenitally deaf and dumb subjects is reported in terms of EEG ratio indices. The frontal and occipital lobes are associated with development of motor skills, cognition, and visual information processing and color recognition. The sixteen hours of First-Person shooter action video game play resulted in the increase of the ratios $\beta/(\alpha+\theta)$ and β/θ in frontal and occipital lobes. This can be attributed to the enhancement of certain aspect of cognition among deaf and dumb subjects.

***Keywords*—**Cognitive enhancement, video games, EEG band powers, Deaf and Dumb subjects.

I. Introduction

VIDEO games are one of the most popular forms of entertainment for all age groups. The effects of playing video games on the cognitive abilities depends on four dimensions [1]. Namely, the amount of playing times and habits (amount), messages carried by the video games (content), kind of knowledge of media (form), and mechanical input and output devices used (mechanics). There are many different types of video games, each of which have different effects.

The regular practice of action video game play can enhance particular cognitive abilities; such as perception and cognition. The performance of the game players was found superior than non game players on these abilities [2], [3]. Playing action video games can also enhance behavioral performance on variety of perceptual tasks [4].

Video game play is an active process and learning is better because of active involvement of the subjects. They produce subtle changes in mental abilities [5] and results improvement in hand eye coordination, spatial cognitive skills, enhanced learning abilities, reaction time, spatial visualization, visual attention, visual anticipation and search strategies, temporal dynamics of sensory attention, exogenous and endogenous attention, task switching [6], [7].

Video games are considered as promising new materials that can strengthen knowledge. The recent investigation is trying to determine the correlation between video game play and their cognitive abilities. Numbers of investigations have proved that, video game play can provide real world psychosocial benefits on the players.

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A. Electroencephalogram (EEG) and Their Band of Frequencies

Electroencephalogram is a record of the electrical potential generated by the nerve cells in the cerebral cortex [8]. The EEG signals can be recorded either by placing electrodes on the scalp (non-invasive) with good electrical contact or by implanting special electrodes in the brain (invasive). The good-recorded EEG signal provides the information about the spatial distribution of the changing voltage with time.

The five EEG frequency bands which are clinically and physiologically important (0.3-30 Hz) are defined [9] as:

The θ band (0-4 Hz), δ band (4-8 Hz), α band (8-12 Hz), β band (13-30 Hz) and γ band (30-70 Hz).These distinct bands of EEG frequencies are associated with unique cognitive performances.

The α wave activity generally appears at the posterior, occipital, and parietal lobes of the brain. The increase of α activity in these lobes indicates, enhancement of certain cognitive functions such as memory, attention, concentration, improved mRT, sensory processing system, and other brain functions [10].

The β activity is visible in frontal, occipital and parietal lobes. This activity is associated with level of wisdom, learning, making responses, mental activation, focused attention, integrated thoughts, and problem solving. The increase of β wave activity in these lobes indicates enhancement of particular cognitive performance [11].

The θ wave activity is regional and may appear in all lobes of the brain. This activity has been associated with a range of cognitive processes such as mental calculation, memory recognition and learning [12]. An increased θ wave activity indicates improved level of concentration and focused attention [13].

Some studies used δ wave activity during different cognitive processes such as attention and concentration related tasks [14], [9]. During working memory, tasks (WMT) the δ band power increased in central, parietal, and temporal lobes of the brain.

The γ wave activity is associated thinking, high level of information, and task processing. They can be used in various cognitive functions such as polysensory integration, sensory motor coordination, working memory, and formation of long-term memories [15]. These waves are highly localized.

The human brain has broadly four lobes: frontal lobe, parietal lobe, temporal lobe and occipital lobe. Each lobe is associated with specific types of information processing. The

frontal lobe is associated with, emotion processes, reasoning and planning, devolvement of motor skills, cognition [11]. The parietal lobe is associated with visual perception, information processing, and spatial reasoning. The temporal lobe is associated with memory, processing of auditory, and speech signals, and processing new information. The occipital lobe is associated with visual spatial processing, and color recognition [16].

B. Deaf and Dumb Subjects

Generally, subjects with hearing loss of ≥ 70dB are referred as deaf. The literature survey [17] enumerated the deficiencies and strengths of deaf subjects. The deficiencies of deaf subjects include: sequential recalling, attention, processing speed, and memory load. The areas of strength are free recall, visuospatial processing, imagery and dual decoding. The areas of these strengths can be enhanced by adopting particular training strategy, such as playing action video games.

Study also suggest that video game play can also enhance visual processing system among deaf subjects [18]-[21]. The deaf subjects were found to have greater central and peripheral visual fields than normal hearing subjects. The study [22] showed that, the enhancement of visual processing was more efficient in congenitally deaf subjects compared to normal hearing subjects. The hearing-impaired subjects possess certain individual cognitive skills that support the understanding of the speech without using hearing aids. The two EEG ratio indices $\beta/(\alpha+\theta)$ and β/θ have been used for the assessment.

II. Methodology

A. Study Design

The subjects participated in this study were young healthy and congenitally deaf and dumb. The total number of subjects participated were 30 in the age group of 13-20 years and all participants were male. The study population was divided into two groups: experimental and control group. The subjects were randomly assigned to either of the groups by block randomization to achieve the balance. A block size of four in the ratio 2:1 is used. The experimental group consisted of 20 subjects while the control group had 10 subjects.

A *Counter-Strike*, which is First Person Shooter game involving active responses and high level real time strategy is selected in this study. The game consists of two groups, counter-terrorists, and terrorist. Players can join either of the team, or they become spectators. The task of each group is to complete their mission by defeating the other group either by killing the opponent group or by achieving the map's objectives. The experimental group played the game one hour per day for 16 weeks in school computer laboratory.

B. Data Recording and Processing

EEG signals were recorded using BIOPAC MP 150 System with Acknowledge 4.0 software using a sampling frequency of 512 Hz. The potential differences between FP1-FP2, F3-F4, C3-C4, P3-P4, O1-O2, F7-F8, T3-T4, T5-T6 were recorded by fixing the CAP100C on the scalp of the subjects head, according to the 10/20 international system. The EEG data was collected under eyes closed condition. Five minutes of baseline EEG signal before pre intervention and 10 minutes EEG data after post intervention period was recorded from each subject in sitting position. The data was saved on the computer hard disk for offline processing. Data were cleaned by excluding eye movements, eye blinks, and any other types of artifacts. Manual editing was performed on EEG signal to obtain clean signal. Any data whose standard deviation was less than or equal to three times the standard deviation was considered outliers and removed from the analysis.

The discrete wavelet transform (DWT) which has the advantage of splitting the signal in both time and frequency plane, and computationally efficient is used to decompose the non-stationary EEG signal. The higher order wavelets are not suitable for precisely detecting and analyzing the fast changing signals such as EEG, as it averages out the detailed signal component. Therefore, db4 which has fewer numbers of coefficients is more suitable for precisely detecting short duration signals such as EEG. Hence, this wavelet function is used to obtain various frequency components of EEG signals. The number of decomposition levels is selected based on the dominant frequency component of the signal. In this study, the EEG signal was recorded with a sampling frequency of 512 Hz. Hence, the EEG signal was subjected to decompositions level of 7 using db4. The decomposition levels and EEG frequency bands are shown in Table I.

TABLE I
EEG Frequency Sub Bands

Decomposition Levels	Frequency bands, Hz	EEG Frequency Sub Bands
D1	256-512	Noise
D2	128-256	Noise
D3	64-128	Noise
D4	32-64	γ
D5	16-32	β
D6	8-16	α
D7	4-8	θ
A7	0-4	δ

An artifact free 10 seconds data were analyzed and compared with baseline values, to find any significant changes resulted due to playing video games.

III. Results and Discussion

The cognitive performance was assessed in terms of two EEG ratio indices $\beta/(\alpha+\theta)$ and β/θ at frontal lobe, parietal lobe, occipital lobe and temporal lobes. The band power of particular EEG changes according to functional conditions of the brain. These oscillatory bands are selectively distributed and functionally related to memory, sensory and various cognitive processes [23]. During game play β activity was found larger in central, temporal and occipital lobes. Also the β and α band power increased in occipital, parietal, and frontal regions compared to the baseline values. The increase of α and β waves reflects the good learning situation. The enhanced β activity reflects the increased cognitive activity, attentiveness,

or dedicated exertion [11]. The overall α activity was found larger than β activity during game play condition. The θ power increased in frontal lobe, and reflects enhancement in certain executive functions. The two EEG band powers β, and θ, were found higher in parietal lobes of the brain. The parietal lobe is stronger in case of deaf subjects [20]. The increase of these powers in this lobe indicates the possibility of improvements in certain cognitive functions. The ratio β/θ is an indicative of neural activity [24] found higher in parietal and occipital lobes and lower in frontal and central lobes and slightly lower in temporal lobes of the brain. The higher α band power was found in parietal, occipital and temporal lobes. The increase in α band power is associated with increased attention. The engagement index β/(α+θ) which reflects the level of the tasks increased in central and occipital lobes.

The effect of two important engagement indices β/(α+θ) and β/θ in different lobes of the brain is shown in Fig. 1. No significant changes were found among control group.

The higher indices values in various brain regions indicate better cognition of alertness and improvement in the cognitive activity. Better cognition means better functioning of the brain and which may be due to larger contribution of neuronal mechanisms that took place in the various cerebral regions. The β band power was found increased in occipital, parietal, and central lobes. As β is associated with attentiveness, active thinking, problem solving, focus on outside world and extremely active awareness. Thus an enhancement in β band power indicates high level of awareness, attention, alertness and improvement in the cognitive skills [11]. The θ EEG band power was found decreased in all lobes accept in parietal lobe. These activities are related to learning, and highly creative states. That is increased theta power reflects decreased concentration [25]. Student's t-test was performed on set of pre and post intervention data samples to investigate whether there was any real difference between them.

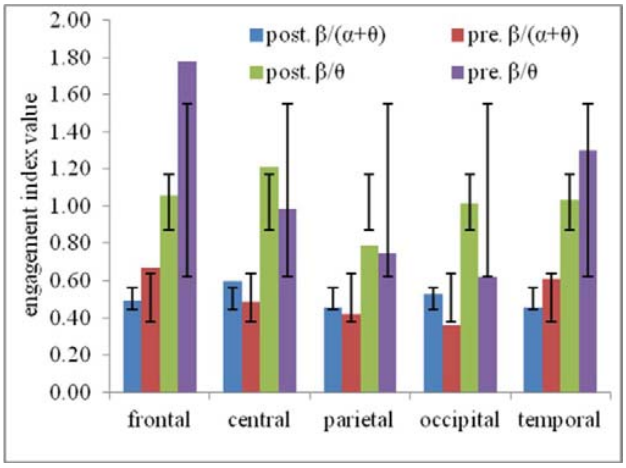

Fig. 1 Engagement index in different lobes

IV. Conclusions

The results of this study reveal that playing action video games can enhance range of cognitive functions among deaf and dumb subjects. The β power increased in central, occipital and parietal lobes while α band power in parietal, occipital and temporal lobes. The increase of β activity in these lobes indicates improvement in visual perception and motor development abilities; whereas the increased α activity attributed to enhancement in memory performances.

The increase of band powers in these lobes are associated with improved visual perception and planning skills. The task load index increased from 0.808 to 1.030. This may be due to the increase of θ activity in frontal lobe which is associated with information processing capacity.

In conclusion, the results presented here indicate that, video game play can enhance certain cognitive abilities among deaf and dumb subjects as in case of normal healthy subjects. The results are promising, and may provide window for further study to correlate the physiological parameters and actual measures of cognitive functions.

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References

[1] Gentile D A, Stone W.: Violent Video Game Effects on Children and Adolescents. A Review of the Literature. Minerava Pediatr 57 (2005): 337-358
[2] Boot W B, Blakely D R, Simons D J.: Do Action Video Games Improve Perception and Cognition?. Frontiers in Psychology 2 (2011):226
[3] Bavelier D, Green C S, Han D H Renshaw P F, Merzenich M M, Gentile D A.:Brains on video games. Nature Review Neuroscience 12 (2011):763-768
[4] Green C S, Li R, Bavelier D.: Perceptual Learning during Action Video Game Playing. Topics in Cognitive Science 2 (2010):202-216
[5] Whitaker J L, BushmanB J.; A Review of the Effects of Violent Video Games on Children and Adolescents. Wash & Lee L. Rev 66 (2009):1033-1051
[6] Latham A J, Patston L L, Tippett L J.: The virtual brain:30 years of video-game play and cognitive abilities. Frontiers in Psychology 4 (2013):1-10
[7] Gentile D A.: The Multiple Dimensions of Video Game Effects. Child Development Perspectives 5 (2011):75-81
[8] Adeli H, Zhou Z, Dadmehr N.:Analysis of EEG Records in an Epileptic Patient Using Wavelet Transform. Journal of Neuroscience Methods 123 (2003): 69-87
[9] Harmony T.:The Functional Significance of Delta Oscillations in Cognitive Processing. Frontiers in Integrative Neuroscience 7(2013):69-87
[10] Chen Z, Meichsner J H, Zou S, Zhao L.: Correlation Between Alpha Rhythm and Cognitive Processe.3rd International Conference on Biomedical Engineering and Informatics (BMEI) (2010): 823-827
[11] Chandra S, Hazarika J, Jha D.: Action Video Games: Its Positive Effect on Cognition. Journal of Computing 3 (2011): 88-92
[12] Klimesch W, Doppelmayr M, Yonelinas A, Kroll N E, Lazzara M, Röhm D, Gruber W.: Theta Synchronization During Episodic Retrieval: Neural Correlates of Conscious Awareness. Cognitive Brain Research 12 (2001): 33-38

[13] Doppelmayr M, Finkenzeller T, Sauseng P.: Frontal Midline Theta in the Pre-Shot Phase of Rifle Shooting: Differences Between Experts and Novices. Neuropsychologia 46 (2008):1463-1467
[14] Başar E, Basar-Eroglu C, Karakaş S, SchürmannM.: Gamma, Alpha, Delta, and Theta Oscillations Govern Cognitive Processes. International Journal of Psychophysiology 39 (2001):241-248
[15] Fries P, Nikolic D, Singer W.: The Gamma Cycle. Trends in Neurosciences 30 (2001):309-316
[16] Shibata D.: Differences in Brain Structure in Deaf Persons on MR Imaging Studied with Voxel-Based Morphometry. American Journal of Neuroradiology 28 (2007):243-249
[17] Hamilton H.: Memory Skills of Deaf Learners: Implications and Applications. American Annals of the Deaf 156 (2011):402-423
[18] Green C S, Bavelier D.: Action Video Game Modifies Visual Selective Attention. Nature 423 (2003):534-537
[19] Bavelier D, Achtman R L, Mani M, Föcker J.: Neural Bases of Selective Attention in Action Video Game Players. Vision Research 61 (2012):132-143
[20] Bavelier D, Hutton C, Mitchell T, Corina D, Liu G, Neville H.: Visual Attention to the Periphery is Enhanced in Congenitally Deaf Individuals. Journal of Neuroscience 20 (2000):1-6
[21] Bavelier D, Dye M W, Hauser P C.: Do Deaf Individuals See Better?.: Trends in Cognitive Sciences 10 (2006):512–518
[22] Stivalet P, Moreno Y, Richard J, Baraud P A, Raphel C.: Differences in Visual Search Tasks between Congenitally Deaf and Normally Hearing Adults. Cognitive Brain Research 6 (1998): 227-232
[23] Başar E, Basar_Eroglu C, Karakaş S, Schürmann Martin M.: Are Cognitive Processes Manifested in Event-Related Gamma, Alpha, Theta and Delta Oscillations in the EEG?, Neuroscience Letters 259 (1999):165-168, 1999.
[24] Freeman F G, Mikulka P J, Prinzel L J,Scerbo M W.: Evaluation of an Adaptive Automation System Using Three EEG Indices With A Visual Tracking Task. Biological Psychology 50 (1999):61-76
[25] Malik A S, Fawzy S M, Osman D A, Khairuddin R H R.: Effect of Movie Clips on Human Brain. In Intelligent and Advanced Systems (ICIAS). 4th International Conference (2012): 95-99