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Effect of Immersion (2D vs. 3D) on Attention through Virtual Reality

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Abstract: ***There are growing evidences which shows the use of Virtual Reality (VR) in numerous fields such as education, real estate, research, data mining etc. However, the role of neural substrate in information processing vary when the level of immersion in VR changes. It leads to variation in performance task based on the attention in the task. There are very few studies which deal with the effectiveness of immersions in display of information with neuroscience. In this experiment, we examined effect of fully immersive 3D VR and less immersive desktop VR environments on the brain. In this, eight participated in spatial navigation task in three modes. Each mode consisted of different times. Electroencephalography (EEG) was acquired during third person's and first person's perspective navigation. After each mode some questions were asked to check the attention of the participants. Result was analysed using energy and power spectral density of Gamma and Alpha bands. Alpha band showed reduction in 3D VR while Gamma Band showed enhancement in 3D VR. The objective score of questionnaires in both 3D and desktop VR showed the amount of alertness. The immersive virtual reality results shows that it had much more immersion and it provided more information compared to Desktop VR. Also, there was increase in alertness in immersive virtual reality. This study confirmed use of 3D VR in displaying information using EEG for enhancing performance in normal and rehabilitation.***

Keywords: Virtual Reality, Immersion, Electroencephalography (EEG), Energy, PSD, Attention

1. Introduction

Virtual reality (VR) is now a known term in every possible fields of arts and science. It is increasing possibilities with the advancement of technology in computer science. Cheap head mounted display (HMD) like oculus rift has enhanced its concernment in applied fields. To implement task in VR successfully, there is a need to understand what kind of immersion can captivate attention of participants. This phenomenon is termed as presence which is entirely participative. Presence can be felt when there is some immersion in VR. To measure the attention in VR, presence can be one of the independent variables that derive behavioural output from the interaction with task. Therefore, it is necessary to assess attention by measuring presence of the participant in a particular task. In this experiment, attention was measure through Electroencephalography (EEG), during spatial navigation and objective questionnaires were asked about the environment.

EEG offers real time assessment of temporal dynamics of brain signals during the task. EEG signals consisted of five wave patterns which are Gamma(30-60 Hz), Beta(13-30 Hz), Alpha(8-13 Hz), Theta(4-8 Hz) and Delta(0.1-4 Hz). In this study we choose Gamma and alpha wave patterns. Spectral analysis of gamma and alpha wave is important in assessing psychological states. Energy and PSD is two important features which determines the attention of participants. Various researches showed how these features changes with the attention. Presence of alpha wave showed rest state of brain (Buzsáki G 2006) while lack of alpha showed brain is engaged in some task that is having attention (Foxe et al. 2011). Also, there was a decrease in alpha band power in response to the imperative stimulus (Klimesch et al. 1998). Gamma band activity played a role in selective attention at intermediate phenotype level (Enge et al. 2014). In one research reverse was done, in which selective attention enhanced signal power of auditory steady-state response in gamma range (Skosnik et al. 2007). Also, it had been strongly correlated with top down attention selection and had network in frontoparietal regions of brain that process relevant features of stimuli (Jensen et al. 2007, Noudoost et al. 2010).

One study was executed to examine the differential effect of 3D versus 2D VR environment on cognitive/motor task along with EEG (Slobounov et al. 2015). Participant felt high presence in 3D when compared to 2D. They also found significant change in frontal central theta power during encoding of route in navigation and it increased during successful performance of perceptual-motor tasks. This suggested that fully immersive 3D VR required more brain resources allocation than 2D VR. Also, 3D VR promoted error monitoring and future learning. It could be a useful technique for enhancing performance in rehabilitation using VR and EEG altogether. But biggest limitation of their study was that they included only theta band and was tested only for one virtual environment. These limitations are overcome by our study.

We selected alpha and gamma band energy and PSD together based on the literature support as above mentioned. One more limitation of that paper was that they didn't perform any questionnaire related to their environment, which is again overcome by us. We included objective questions that could show degree of attention in 2D and 3D VR. In the next section methods, results and discussions are included. It will demonstrate the usefulness of navigation in 3D VR when compared to 2D VR environment.

2. Materials and Methods

Human subject, Virtual Park scenarios, EEG signal acquisition, MATLAB used for the analysis of EEG signal with the help of Wavelet Transform etc.

Participants
Eight healthy participants aged 22-26 (4 male and 4 female) years were participated in this study and no participant had any medical illness, brain injury, psychiatric or cardiac history or were taking prescription drugs.

Virtual Park Scenarios

Three different park scenarios were developed using Unity 4.5. The scenarios were in both two dimensional displays (2D) and three dimensional displays (3D). For 2D, desktop version of VR was used while immersive VR was shown using stereoscopic goggle. Virtual Park scenarios were created with different texture and objects to judge effect of environmental properties on attention. The first scenario had rich set of texture and fewer objects. The flying camera was placed at more height. The time period of this scenario was about 120 seconds. The second scenario had good amount of texture and objects. The time period of this scenario was 85 seconds. The flying camera was situated at less height as compared to first scenario. The third scenario had a fair amount of texture and objects. The time period of this scenario was 80 seconds. The flying camera was situated at less height as compared to all scenarios. The users could easily navigate into the environment by using a joystick.

Data Acquisition
Wireless Emotiv EPOC neuroheadset is a very efficient tool which was used for acquiring the EEG signals. It is very user friendly hardware. It is a fourteen channel plus Common Mode Sense (CMS) active electrode/ Driven Right Leg (DRL) passive electrode references, P3/P4 locations. Device having a sampling frequency of 128 Hz, It has resolution of 14 bits, bandwidth of 0.2 - 45Hz, digital notch filters at 50Hz and 60Hz.

Feedback Questionnaires for attention measurement
In this research questionnaire were created to analyze the attention. The Feedback Questionnaire (FQ) was based on fine details of the various scenarios. Formulated questions were such as "Was there any red box over there?" or "Was there any blue wall?" After each scenario five questions were asked to the participant. The questionnaires were different in desktop VR and 3D VR environment. Questions were randomised for each participant to remove any biases.

Procedure
Environment was presented in system having 15.6" display size, 4GB Ram, Intel i5 processor. Participants were shown three different virtual park scenarios in 2D and 3D mode with mixed randomised trials. One practice session was conducted to make the participant comfortable with gadgets like joystick and the stereoscopic goggle. In this research work the user navigated by flythrough camera function in one trial and then with the help of joystick in next trial. Total twelve trials were played by the participants. Simultaneously EEG signals were acquired for each scenario. During recording session all metallic objects and mobile phones were kept away from the participant as well as administrator to minimize the external noise. Participants were asked to minimize muscle movements. After watching the scenarios the FQ were asked for analysis of attention for the comparative study of 2D and 3D VR environment.

EEG Signal Analysis
Pre-processing of EEG raw signal included segmentation, noise removal and frequency division. Normalization was done by subtracting the mean value of signal from the raw signals. It reduced the effects of individual differences due to their fundamental frequency rhythms and the computational complexity. A 50 Hz notch filter was used to remove power line interference from the acquired signals. Wavelet soft de-noising was used to de-noise the signal, from the wavelet packet co-efficient reconstruction, different frequency bands of EEG were reconstructed. In this study, only Gamma and Alpha bands were reconstructed.

Feature Extraction

Energy
Wavelet packet node energy is more robust in representing a signal than using the wavelet packet coefficients directly. According to Parseval‟s theorem, the energy of the distorted signal can be partitioned at different resolution levels. Total signal energy can be defined in equation (1).

$$E = \sum_{j=1}^{N} |C_{ij}|^2 \quad (1)$$

i=1, 2……l
Where i=1,2……l is the wavelet decomposition level from level 1 to level l. N is the number of the coefficients of detail or approximate at each decomposition level. In order to analyze specific frequency region, suitable tree structure should be chosen, which represent the wavelet packet energy distribution in that tree.

Power Spectral Density (PSD)
Power spectral density function shows the strength of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are strong and at which frequencies variations are weak. The power is calculated using PSD concept. The estimated PSD provides a lot of information about the signal which will be considered for modelling and prediction of signal characteristics. The PSD of a signal provides lots of information about the signal including signal characteristics.

For a finite length signal xl (n) of length l the PSD is calculated by, multiplying the Fourier transform of the filtered signal with the conjugate of that filtered signal and is given by equation (2).

$$F[r_{xx}(1)] = I_l(w) = \frac{1}{l}\{F[x_l(1) * x_l^*(-1)]\} \quad (2)$$

Where $r_{xx}(1)$ is the biased autocorrelation estimate and $I_l(w)$ is known as period-gram.

Statistical Analysis
For statistical analysis of EEG data and FQ the multivariate analysis was used. It‟s a tool box of Statistical Package for the Social Sciences (SPSS) software. The multivariate analysis correlated all the parameter to each other and gave the mean and standard deviation values. The dependent variables like Energy, PSD and answers of FQ were compared through unpaired sample t-test with keeping significance level (α) at 0.05.

3. Results

In the present research work, EEG signals were picked up with the help of Emotiv Head Set at F3, F4, O1 and O2 channels by giving visual stimulus in both 2D and 3D VR environments. Occipital lobe was engaged in processing of visual stimuli while Frontal lobes found to be activated mostly during attention. The mean and standard Deviation values of energy and PSD of alpha and gamma band were calculated corresponding to 2D VR environment and 3D VR environment. Alpha Energy and PSD reduced for 3D VR environment as compared to 2D environment, while energy and PSD of Gamma band increased for 3D VR environment as compared to 2D environment. Scores in FQ increased for 3D scenarios when compared to 2D as shown in Fig.1. Although results were insignificant by applying t-test due to small sample size, but differences were evident between 2D vs. 3D.

4. Discussion

The objective of the present study was to compare differences in brain activities in 2D and 3D mode due to differences of immersion. It was in effect of variation in attention during navigation. Three virtual scenarios were compared for 3D versus 2D with EEG and questionnaire for attention. Participant navigated in one scenario in four trials, which were in 2D and 3D, with joystick and fly through camera. In total, twelve trials were performed by each participant with alteration of order to removes any biases.

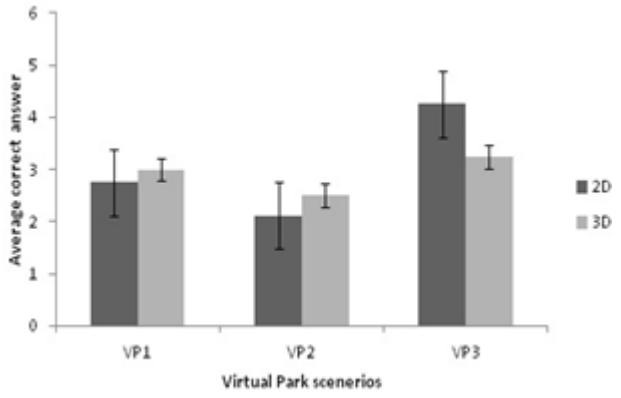

Fig.1 it showed subject's average correct score for Feedback questionnaire for three virtual park scenarios in two different modes. Here VP1, VP2 and VP3 represented virtual park scenario 1, 2 and 3 respectively.

It was considered that more immersion in the VR environment would have more alertness that increased the attention of participant. In other words, if participant felt more presence in one virtual scenario then its encoding would be more which would be reflected in his EEG. In previous paper (Slobounov et al. 2015) it was shown that frontal central theta increased during encoding phase (Slobounov et al. 2011) which reflected great sense of presence. They proved high immersion could induce great sense of presence which alleviated alertness. One limitation of this paper was that only theta feature were analysed with one virtual environment. Here in our study, we changed scenarios from less number of objects to more number of objects. Also, two EEG features i.e. energy and PSD were computed for visualising the effects of immersion on attention. Result gave evidence of visual attention activity and increase in alertness during the participant„s interaction with the 3D virtual reality environments. The decrease in alpha band showed an increase in attention activity with the 3D VR environment which indicated the participants were transit to wake-up state. Moreover, the increase in gamma band showed the participants were in thinking or in reasoning state and analyzing the scenario„s information The scene realism and information consistence with the virtual reality that was involved in the environmental richness and visual attention caused the observed alpha wave reduction in the frontal and occipital lobes. Result was consistent with previous studies (Skosnik et al. 2007, Jensen et al. 2007, and Noudoost et al. 2010).The results of feedback questionnaires proved the 3D virtual reality had more alertness activity in scenario 1 and scenario 2. The scenario 3 had more significance in 2D because it had less solid object which was easily recognizable in 2D as compared to 3D VR. Combined (EEG+ immersive VR) provides valuable assets in various fields to increase attention that ultimately enhances the performance regardless of any application. The capacity of VR is to create dynamic, immersive three dimensional stimulus environments, in which all behavioural responding can be recorded. It offers assessment and manipulation options that are not available using traditional assessment methods.

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