

Measuring Presence During the Navigation In a Virtual Environment Using EEG

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Abstract. In the Virtual Reality field, presence refers to the sense of “being there” in the virtual world. Our aim in this work is to evaluate the usefulness of the Emotiv EPOC EEG device to measure the brain activations due to the sense of presence during the navigation in a Virtual Environment (VE), using for the analysis the sLORETA tool. We compare between two experimental conditions: free and automatic navigation through a VE. In this preliminary step, we monitored 9 healthy subjects, obtaining significant differences between the free and automatic navigation conditions in the activity of the right insula for the Theta and Alpha bands. The insula activation is related to stimulus attention and self-awareness processes, directly related with the sense of presence.

Keywords. Presence, Virtual Reality, EEG, sLORETA

Introduction

In the Virtual Reality (VR) field, presence refers to the feeling of being there, inside the VE, while your body is physically located elsewhere [1]. As Kober et al. [2] remarked, the greater the degree of presence the participants feel, the greater the chance they will behave in the VE as they would do in a similar real world setting. One technique that has been proposed and applied for presence measurement is the electroencephalography (EEG), due to the freedom of movement the subject has once the electrodes are placed, especially in comparison with techniques that impose severe restrictions to movements such as fMRI. EEG measures the electric activity in the brain; more specifically, it measures the synaptic potentials in the cerebral cortex. EEG signals show the difference in potential between two electrodes, an active one and a reference one. The time resolution of the technique is of the order of milliseconds, allowing the measure of the fluctuations in the EEG signal due to the tasks developed.

Until now, several studies have been made combining VR with EEG to measure the sense of presence experienced by the subjects. For example, Baumgartner et al. [3] evaluated the cerebral activity related to the sense of presence using a multichannel EEG, applying the low-resolution brain electromagnetic tomography (LORETA) method to study the cortical structures that produce the neurophysiologic activation.

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They compared activations between children and adolescents while viewing a video of a rolling coaster, and found activation in the parietal areas of the brain.

More recently, other studies were developed in interactive environments where the navigation through the virtual environments was allowed, in order to increase the sense of “being there”. Kober et al. [2] analyzed spatial presence in an interactive virtual world, comparing two systems for the presentation of the virtual stimuli: one based on a high-immersive VR wall (3D) and another based on a low-immersive 2D desktop screen. The 3D screen system showed a greater presence sense associated with an increase in the Alpha band for the parietal TRPD (“Task-related power decrease”), related to the parietal activations. The lower presence experience in the 2D screen was accompanied by a strong functional connectivity between the frontal and parietal areas of the brain, pointing out that the communication between those areas is crucial for the experience of presence.

In another study, Kober and Neuper [4] studied the Event-Related brain Potentials (ERP) of the EEG signal, which were elicited by tones that were not related with the VR experience and were used in the experimental design to obtain an objective indicator of the experience of presence in the virtual environment. They found a correlation between the increase in the presence experience and the decrease in the late negative slow wave amplitudes, related to the central stimulus processing and the allocation of the attentional resources. According to this conclusion, an increase in presence is related to a greater pay of attention to the virtual environment, which leads to a decrease in the attention paid to the irrelevant stimulus of the VR (decrease in the ERP components due to the tones).

In these previous studies, the influence of user-controlled navigation on the presence experience and on the associated brain activations was not directly evaluated. In order to evaluate this issue, for our present study, the goal will be to compare brain activity due to presence between two experimental conditions: the view of a video of an automatic navigation and a free navigation through the VE. We expect that the sense of presence will be greater in the navigation condition than in the video condition, and that there will be differences in brain activation in areas related to presence, which will be generated by the changes in the presence experience between conditions. Moreover, for this study we will use a wireless portable EEG device, which will allow a quicker placement of the sensors and a higher degree of movement in the subject.

1. Material and Methods

1.1. Subjects

For a preliminary study, 10 healthy subjects (6 men, 4 women) were evaluated, all of them right-handed and with ages between 22-29 years old. All of them provided signed consent for allowing their data being used in this study. One subject (a woman) had to be excluded due to movement during the scan. The experiments were conducted in a laboratory inside the LabHuman institute. The EEG signal was monitored by means of a multichannel wireless portable EEG device (Emotiv EPOC) [5], which has 14 data-collecting electrodes and 2 reference ones. The handset transmits wirelessly the EEG data to the computer. For showing the VR environments, a desktop screen was used.

1.2. Presence Questionnaire

After the EEG session, subjects had to answer the questions of a SUS questionnaire [6] to evaluate the level of presence that they felt during each task (one questionnaire for each experimental condition). The questionnaire consisted in six 7-point Likert type questions that had to be answered depending on the strength of the “being there” sensation experienced, where 1 corresponded to not feeling there at all and 7 to the highest sense of being there (as experienced in the real world).

1.3. Environments

The virtual environments were programmed using GameStudio software (Conitec Datensysteme GmbH, Germany), which allowed us to develop 3D objects and virtual worlds with which we could interact and navigate. Our virtual environment (VE) consisted of an everyday, clean bedroom (with a bed, a closet, and a desk with some books on it) where participants could navigate freely.

To allow us to identify the specific areas of the brain that were activated for each task, we divided the paradigm into two conditions developed with the same virtual environment: in the first, a video of an automatic navigation through the room is observed; in the second, the participant can navigate freely in the VE.

Each condition was repeated six times. To learn about the tasks that had to be performed inside the scanner room, subjects underwent a prior training session. In order to prevent differences in activation caused by the motor task, subjects were instructed to move the joystick continuously during the video task in the same way as they did during the navigation period.

1.4. Data Analysis

For the questionnaires, we carried out a non-parametric Wilcoxon Signed-Rank test to compare SUS responses for the questions 1-6 and for the SUS mean, between the free and automatic navigation conditions.

The preprocessing of the signals was made by means of the EEGLAB program [7]. All recorded EEG epochs were checked for artifacts. First of all, data were digitally filtered using a linear FIR band pass filter (0.5-45 Hz). Then, the electrooculographic (EOG) artifacts were removed applying Blind Source Separation (BSS), using a window length of 10s, with 5s between windows. The electromyographic (EMG) artifacts were removed using also the BSS method.

For the analysis of the activated brain areas, the sLORETA (standardized low-resolution electromagnetic tomography) tool was used [8-11]. The whole brain was analyzed using voxel-wise LOG t-tests for examining the navigation vs. video conditions in the six frequency bands.

2. Results

A Wilcoxon Signed-Rank Test was conducted to compare between the six questions and the SUS mean results corresponding to the video and to the free navigation. A

statistically significant increment was found in the navigation scores with respect to the video scores for all the six questions and the SUS mean results ($p < 0.05$).

Table 1. SUS responses to questionnaires for each task (mean score and standard error of the mean) and results of the Wilcoxon Test for each question and the mean score

	Video	Navigation	Z	P
SUS question 1: feeling of “being there”	3.11±0.31	4.89±0.39	2.714	0.007
SUS question 2: feeling that the room is real	3.00±0.33	4.78±0.40	2.724	0.006
SUS question 3: how real do you remember the room?	2.67±0.24	4.11±0.39	2.565	0.010
SUS question 4: feeling of being inside the room or observing it	2.89±0.51	4.78±0.49	2.588	0.010
SUS question 5: memory of the room as similar to being in other places	2.89±0.39	3.78±0.49	2.271	0.023
SUS question 6: did you think you were really in the room?	3.22±0.28	4.78±0.47	2.392	0.017
SUS mean	2.96±0.24	4.52±0.35	2.668	0.008

For the EEG data, the comparison between the Navigation and Video conditions using voxel-wise log t-test for all frequency bands revealed significant differences in the Alpha-band (8-12 Hz) and Theta-band (4-7 Hz), for $p < 0.05$. Alpha and Theta band power was decreased in the Navigation condition in the right Insula (BA 13), indicating increased activity in this region during the free navigation task. There has been also found a trend ($p < 0.1$) to increased activity in the Prefrontal Gyrus (BA 43) for the Alpha-band.

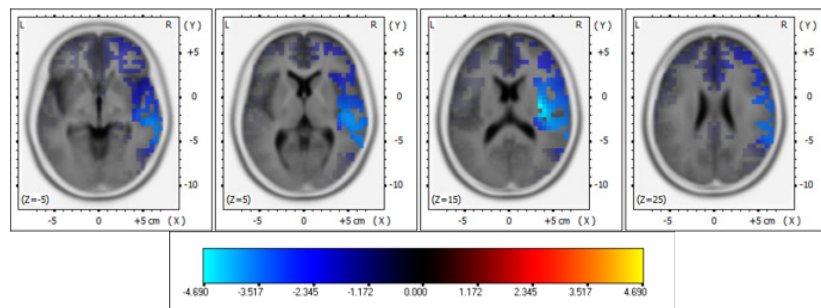


Figure 1. Capture of sLORETA activation in the Insula.

3. Discussion

As aforementioned, we have found activation in the insula. This area is related to emotion and regulation of the body’s homeostasis, which includes among other functions self-awareness or the sense of agency and body ownership [12]. The sense of body ownership is the property which allows you to discriminate your own body and perceptions; forming the “body schema” which guides your behavior [13]. Recent works [14] have found evidence that the right insula may be activated by a combination of attentional and response control demands, playing a role in the processing of sensory stimuli that are relevant to the current goals. While navigating in a VE, you make decisions all the time, based on the evaluation of the sensory stimuli that guides our behavior in the VE. Our results suggest that the insula may play a key role in guiding behavior in the virtual environment based on the presented stimuli and the sense of presence. Moreover, according to Sjölie [15], attention and behavior are essential to develop the sense of presence, increasing the precision in the predictions about the

environment and the synchronization with it, and avoiding prediction errors from sources outside the VE.

Regarding the questionnaire results, they confirmed that a higher level of presence was induced during the free navigation than during the automatic navigation. Specifically, the Wilcoxon Test showed significant differences between the experimental conditions for all the questions and the SUS mean with higher presence values for the navigation condition.

Finally, we would like to emphasize that our results are consistent with those obtained in previous researches, which validates the possibility of using the Emotiv EPOC EEG portable device for this kind of studies.

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