RAVE-10 Abstract

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Cortical correlate of spatial presence in 2-D and 3-D interactive virtual reality: An EEG study.

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Abstract

The concept of spatial presence that is defined as "the sense of being in an environment"[1] has received great attention in connection with virtual reality applications. The success of virtual reality is thought to be associated with the subjective feeling of presence. Various studies examined different factors that enhance the feeling of presence, like a stereoscopic presentation, image motion, screen size, a realistic design and so forth[2,3,4,5]. In addition, there is a growing interest in the neuronal underpinnings of presence, although there are to date only a few studies investigating the neurophysiological correlates of spatial presence. Presence is associated with activation of a distributed network that includes among other things the dorsal and visual stream, the parietal cortex, the premotor cortex and the dorsolateral prefrontal cortex. There is evidence that an increase in spatial presence is accompanied with an increase in parietal brain areas known to be involved in spatial navigation and a decrease in frontal brain areas[6,7,8]. It is assumed, that the dorsolateral prefrontal cortex down-regulates the activation in the dorsal visual processing stream[8]. One limitation of these studies is that the cortical activation was only measured in noninteractive, passive viewing spatial presence conditions and not in interactive virtual environments, where for example the subjects were able to move around the virtual world. Hence, it is not clear if the brain activation patterns found in passive viewing conditions during increased spatial presence can be found in other particular virtual environments too. Therefore, the present study examined the relationship between spatial presence and cortical activation using multi-channel EEG in an interactive virtual environment. Moreover, we compared the feeling of presence and the cortical activation in two different virtual reality systems, a highly immersive Single-Wall-VR system (stereoscopic view, 3-D, 2x2 meter projection screen) and a less immersive Desktop-VR system (monoscopic view, 2-D, 20 inch computer screen). According to the literature a stereoscopic view and a larger screen size should enhance the feeling of presence more than a monoscopic view and a smaller screen size[2,3]. If an enhanced spatial presence is accompanied with an increased parietal activation, the parietal activity should be higher in the more immersive Single-Wall-VR condition than in the less immersive Desktop-VR condition.

Thirty-one participants (16 men, 15 women) performed a spatial wayfinding task in a virtual maze, that was either presented in a stereoscopic (Single-Wall-VR, 3-D, highly immersive; 8 men, 7 women) or monoscopic view (Desktop-VR, 2-D, less immersive; 8 men, 8 women). Subjects used a computer keyboard to navigate through the virtual maze. The virtual maze comprised a series of corridors, each leading to a junction with three turnoffs. The participant's aim was to navigate as quickly and accurately as possible from a starting point to a goal point. In a learning phase, arrows were placed at the junctions directing the subjects through the maze. In the test phase, the arrows were removed, so that the subjects had to rely on a learned representation of the maze. During the navigation task the EEG was recorded monopolarly from 21 scalp-electrodes that were attached according to the international 10-20 system. For statistical analysis of the EEG data the percentage change in Alpha band power (8-12 Hz) between a baseline condition and the active navigation condition was calculated (event-related desynchronisation/event-related synchronisation ERD/ERS)[9]. Subjective presence ratings during the wayfinding task were used to determine the subjective feeling of presence. Therefore, the subjects had to rate the intensity of their sense of being in the maze on a scale from 0 to 4 after each navigation trial.

Here we show that according to the literature a stereoscopic view (Single-Wall-VR, highly immersive; $M = 2.68$ points; $SE = 0.17$) enhanced the subjective feeling of presence more than a monoscopic view (Desktop-VR, less immersive; $M = 2.17$ points; $SE = 0.17$) of the virtual environment ($F(1,29) = 4.65$, $p < 0.05$), and that this increased feeling of presence in the Single-Wall-VR condition is accompanied with an increased parietal activation (see Figure 1). At parietal sites the cortical activation was higher in the highly immersive Single-Wall-VR condition than in the less immersive Desktop-VR condition. At frontal sites no differences in Alpha-ERD values between Single-Wall-VR and Desktop-VR could be found. In the Single-Wall-VR condition Alpha-ERD was more pronounced at parietal brain areas than at frontal areas, whereas no differences between parietal and frontal areas could be found in the Desktop-VR condition (see Figure 1; significant interaction between region of interest (ROI) and VR condition ($F(6,174) = 2.86$, $p < 0.05$). There was no difference between the navigational

performance in the Desktop-VR condition (M = 311.33 virtual meters, SE = 7.91) and the Single-Wall-VR condition (M = 298.87 virtual meters, SE = 2.74; $t(29) = 1.49$, $p = 0.15$).

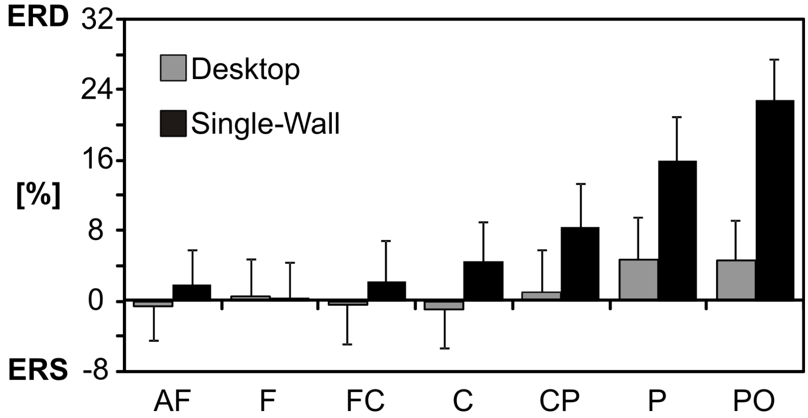

Fig. 1. Bar graphs show means and standard errors in ERD/ERS of Alpha band power (8-12 Hz) during the spatial wayfinding task in the seven regions of interest (AF (AFz, AF2, AF4), F (Fz, F2, F4), FC (FCz, FC2, FC4), C (Cz, C2, C4), CP (CPz, CP2, CP4), P (Pz, P2, P4), PO (POz, PO2, PO4)) separate for the Desktop-VR and Single-Wall-VR condition.

Our results show that the relationship between spatial presence and cortical activation found in noninteractive virtual realities[6,7,8] could also be found in interactive virtual reality-systems that evoke different spatial presence. Therefore, we could support former findings of a positive relationship between spatial presence and parietal activation in an interactive virtual reality paradigm. Furthermore, our findings indicate that the well studied factors that enhance the feeling of presence, like a stereoscopic presentation and a larger screen size, also lead to a different cortical activation. In the Single-Wall-VR condition that provided a stereoscopic view of the virtual environment on a large projection screen the spatial presence was as expected higher than in the Desktop-VR condition that provided a monoscopic view of the virtual environment on a conventional computer screen. The enhanced feeling of presence in the Single-Wall-VR condition was accompanied with an increased parietal activation and a decreased frontal activation. This increased parietal activation in the Single-Wall-VR condition can not be lead back on spatial navigation because the spatial performance was the same in both virtual reality conditions.

Our results have practical implications on rehabilitation techniques in virtual realities addressing the impairments, disabilities, and handicaps associated with brain damage[10]. An enhanced parietal activity due to a higher feeling of spatial presence in a highly immersive virtual environment might facilitate or support the cognitive rehabilitation training (e.g. spatial ability training) in virtual realities when the damaged brain area is at parietal sites. Further studies are needed to examine the influence of an enhanced spatial presence in a virtual environment on the rehabilitation success of brain damaged patients.

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