Human brain dynamics during navigation with natural walking under different workload conditions in Virtual Reality (VR) by using the Mobile Brain/Body Imaging (MoBI) approach

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Abstract

Spatial navigation is a complex cognitive process based on proprioception, vestibular, and visual cues that are integrated and processed by a wide network of brain areas. The retrosplenial complex (RSC) is an integral part to coordinate and translate between egocentric and allocentric reference frames. Previous works using electroencephalography (EEG) revealed navigation related modulations in different frequency bands in the RSC. However, these studies were based on stationary setups which might not be comparable to the cognitive processes during spatial navigation while naturally walking.

We applied the Mobile Brain/Body Imaging (MoBI) approach to study the human brain dynamics in an ambulatory Virtual Reality (VR) setup. In each trial, the participant was first prompted with one landmark and was instructed to remember the location of the landmark which then disappeared. They then physically navigated paths including two or three turning points. After first navigation phase, participants had to point to the non-visible landmark and subsequently had to memorize a series of letters to indicate, after a short rehearsal interval, whether a target letter was part of the learned set or not. Then, participants navigated a second path including two or three turns while memorizing the positive set and the landmark location. At the end of the second navigation phase, participant again pointed to the landmark.

Seventeen participants (two females) participated in the experiment. The neurophysiological data was collected with a wireless 64-channels EEG system (LiveAmps, Brain Products). EEG data was analyzed using Independent Component Analysis (AMICA) with subsequent source reconstruction of brain components using equivalent dipole modelling. The closest brain region of interest (ROI) to the RSC Talairach location (x=0, y = -45, z = 10) was found by using repeated k-means methods (n = 10000 repeated times) using Independent Components (ICs) properties.

In this study, the results of event-related spectral permutation (ERSP) at RSC showed an upper alpha band (10-12Hz) decrease when the participant actively explored the virtual environment, which concurred with previous stationary experiment using a 2D display. Moreover, there was a delta (1-4 Hz) and theta (4-7 Hz) band ERSP increase after each turning points where participant changed their orientation, which indicates RSC may coordinate with other brain areas like hippocampus to update position of landmarks. In addition, we found that there was a significant decrease in upper alpha and low beta (12.5-15 Hz) bands at RSC in second walk condition, reflecting an influence of the workload to RSC activity.