A high-field human brain interface using a modular virtual environment system for real time fMRI

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Introduction: In recent years, the field of virtual reality (VR) environments and neurofeedback applications for functional magnetic resonance imaging has grown. Often this artificial world is theorized to contribute to the successful pain reduction observed in burned patients as well as for therapy of phobias and posttraumatic stress disorder [1]. Other groups applied VR for fMRI-based neurofeedback paradigms and human brain interfaces [2][3][4]. However, VR applications are usually adjusted to the individual tasks and not very flexible to use even in slightly changed paradigms. Our aim is the development and implementation of a VR paradigm library with some common VR scenes and a well-structured modular virtual environment system that allows the import of these virtual reality measurement paradigms just by few mouse clicks. For testing our approach, we used the system as a real time human brain interface where subjects navigated through a three-dimensional maze using brain activations of different cortical areas.

Methods: To assure a consistent change of all parameters during the measurement we extended a previously described XML-based real-time system [5]. The three dimensional maze, modelled with *3D Studio Max* [6], consists of three mazes connected by vertical corridors (fig. 1). The implementations of the avatar inside the VR as well as other VR features were realized using the *Vision Game Engine* from *Trinigy, Inc.* written in C++ [7]. The activation-extraction-system supports spatial filtering and statistical algorithms for data evaluation. Afterwards the results of the statistical data analysis were passed to the activation analysis system, which uses maximum intensity projections (MIP) based on region-of-interest-extraction to extract relevant activated regions from the current statistical MIP's. For our test-case, these extracted patterns are used to move the subject into the desired direction. We scanned at a 3T and a 7T Siemens MRI scanning device. We modified the standard EPI-BOLD sequence and implemented an EVA protocol or used the real time export function from Siemens to allow online saving of the functional images as the prerequisite of real-time analysis. For scan parameters we used: TR= 2000ms, TE= 29ms (3T Scanner) / 20ms (7T Scanner), Resolution= 64x64x31 (3T) / 64x64x16 (7T).

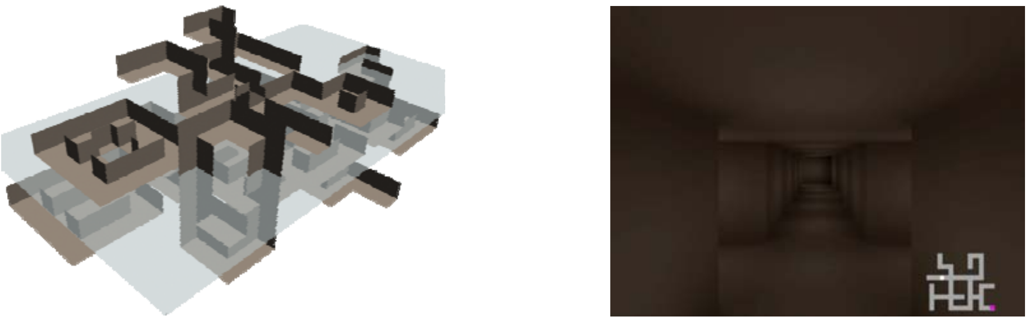
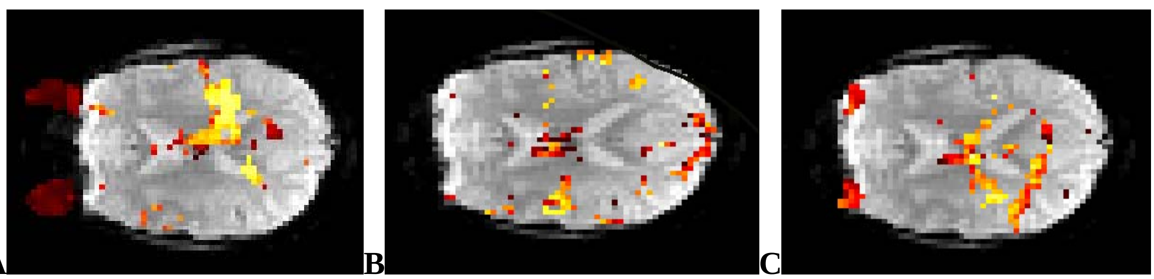


Figure 1. The three-dimensional maze with three floors (left picture) and a l*ook inside the three-dimensional maze (right picture).*

Results and discussion: Experiments were successfully performed. The described system was able to differentiate between the three trained activation patterns of the subjects finger-tapping: left hand (figure A), right hand (figure B) and mental calculation (figure C) - depending on the spatial expansion and strength of the activation. With those results the volunteers could move through the three dimensional maze in three directions. See figures for examples of the extracted and analysed activation of a sample condition. Computation time for the extraction and analysis of the activation was about one second for whole brain images of the mentioned dimensions. With this application we succeeded to design a approach for an application which combines an three dimensional Virtual World for real-time fMRI and a human brain interface.



A B C

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