Non-invasive functional mapping of brain activity

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Introduction

Monitoring and interpreting (sub)cortical reorganization after brain injury may be useful for selecting therapy and improving rehabilitation outcome. Inverse mapping methods allow reconstructing the cortical activity from non-invasive electroencephalographic (EEG) signals with high temporal resolution. Usually a-priory knowledge on brain functioning and patient behavior is used to limit the solution space. The aim of this study was to explore the usability of inverse mapping without including a-prior information.

Methods

Thirty channels EEG was recorded from nine healthy, right-handed female volunteers during 7-s cue-guided imagery trials (random inter trial period 2.5-3.5s). At t=-0.5s a beep and at t=0s a visual cue on the mental task to be performed was presented as shown in figure 1. Seven distinct mental tasks were recorded [1]. In this work we focus on the kinesthetic imagery of right hand movement task.

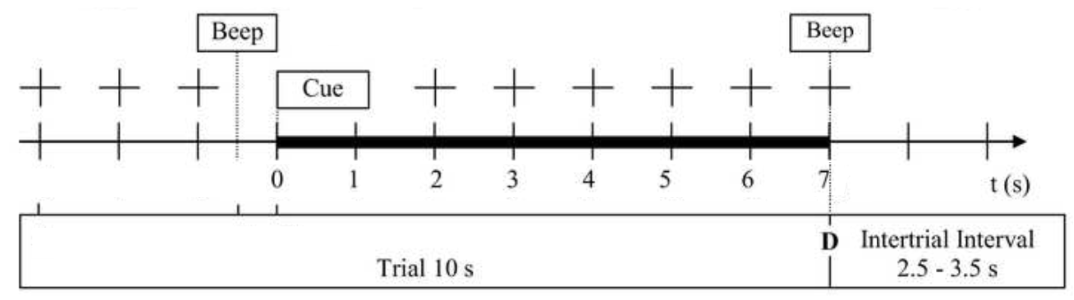


Figure 1: Experimental paradigm timeline

The source estimation is based on a realistic head model. We warped the standard model of the MNI/Colin27 brain using individual EEG sensor positions (Zebris, 3-D). The model consists of four surface layers (brain, inner skull, outer skull, head surface). Based on the shape of these surface layers and the conductivities of the specific tissues a mathematical model was formulated [2]. This model represents the electromagnetic relations between the brain activity on the cortex and the surface potentials measured with the EEG electrodes. We used a weighted minimum norm least squares method to calculate electromagnetic activities on the cortex surface [3]. Subsequently, we calculated Z-score normalized cortical source power averages and computed time-frequency maps that illustrate the activities as a function of time and frequency. Furthermore, we focused on the auditory, visual and motor-sensory cortex as shown in figure 2 to analyze the time course of the electromagnetic activities during the task.

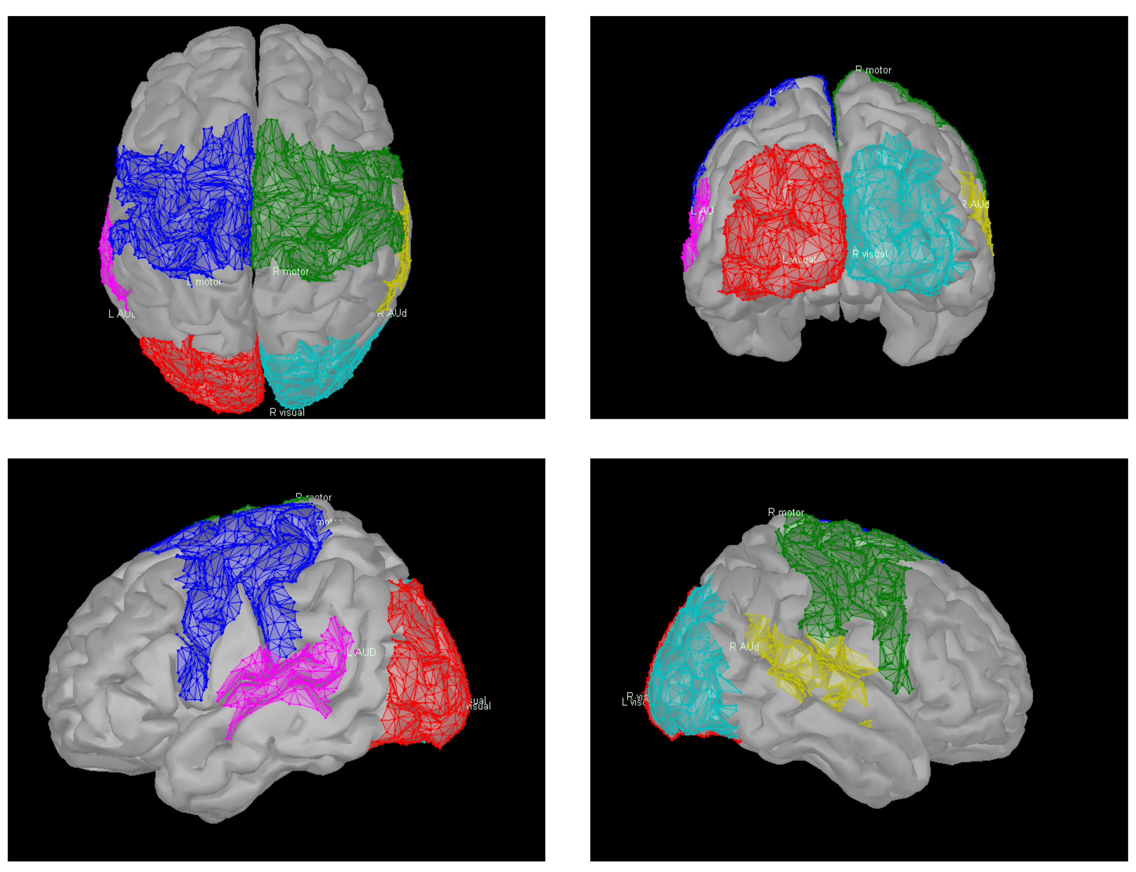


Figure 2: Selected brain areas: auditory (BA 22, 41, 42), visual (BA 17, 18, 19) and motor-sensory (BA 1, 2, 3, 4, 6) cortex

Results

Based on the time-frequency map (figure 3) the feature frequency range of $8 - 14Hz$ was chosen for the kinesthetic imagery of right hand movement task.

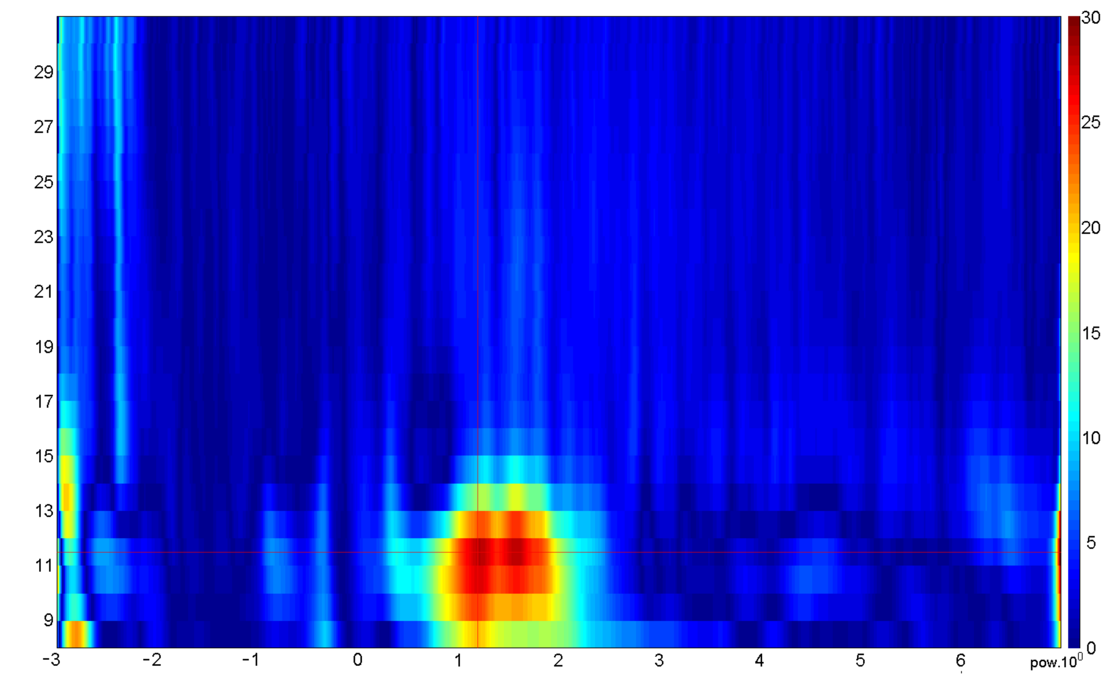


Figure 3: Time-frequency plot of the average trial

The time courses in figure 4 showed an increase after the acoustic signal for the auditory areas. A maximum of the visual cortex activities occurred just after the trial onset. This represents the visual perception of the task instruction. The major activities for this task were located in the motor and premotor areas indicating the motor imagery as represented in figure 5.

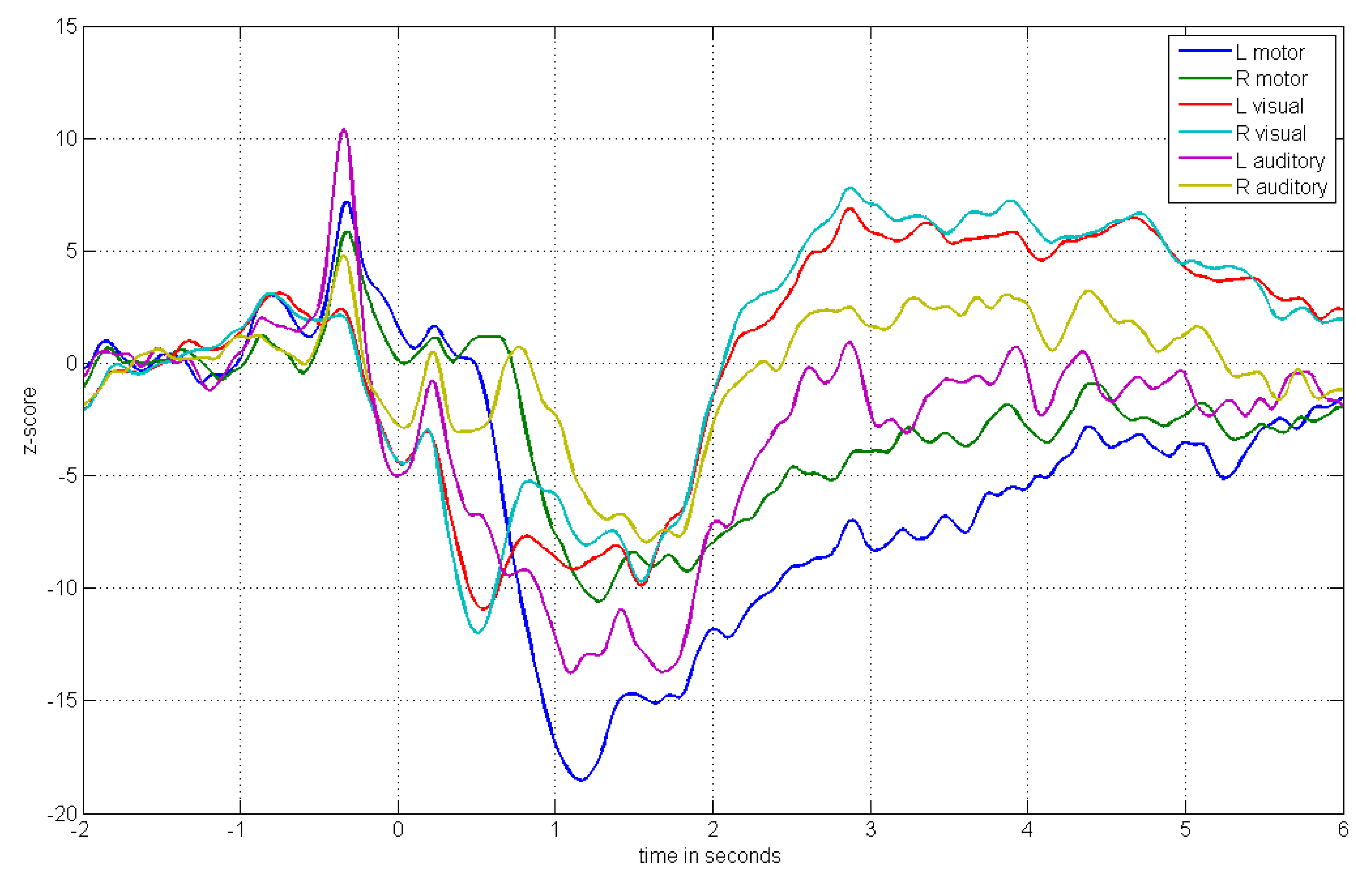
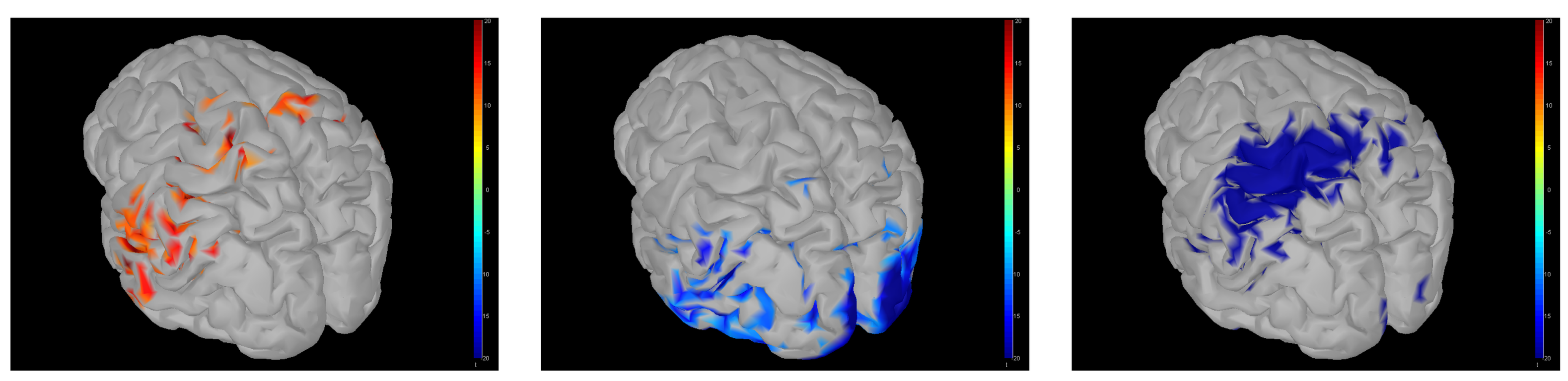


Figure 4: Time course of the mean activity within each selected brain area



auditory activity, t=-0.359s — visual activity, t=0.500s — motor-sensory activity, t=1.156s

Figure 5: Functional mapping of the maximum activity in each selected area

Discussion

Our results showed activity patterns over cortical areas that are related to auditory and visual processing and for motor imagery. Hence, our results support the usefulness of inverse mapping methods for functional brain mapping when the time-frequency range of the electromagnetic activities and the localization on the cortex is unknown. This non-invasive method may be useful in analyzing (sub)cortical activity after brain injury.

References

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