Abstract

Neuronal electrical activity is an indispensable aspect of human brain functioning. Electroencephalography (EEG) and magnetoencephalography (MEG) are two important techniques that enable the comprehensive investigation of brain activity. Recording EEG and MEG in the presence of artefact sources as e.g., heartbeat or brain stimulation devices is very difficult. Artefacts can vastly mask the acquired neurophysiological information. So far, it is very challenging to remove the artefact completely and to retrieve all the neurophysiological information.

This thesis aimed to explore the characteristics of artefacts that arise in simultaneous EEG and functional magnetic resonance imaging (fMRI) recordings as well as in MEG recordings during deep brain stimulation (DBS). Therefore, a new method making use of the available information on the artefact was developed to remove the artefacts and retrieve the signal of interest.

This thesis comprises three studies: Study 1 addressed the so-called cardio-ballistic artefact that is a major problem in combined EEG/fMRI projects. Combining both high temporal and high spatial resolution by means of simultaneous EEG and fMRI is of high relevance for brain research. This combination, however, leads to a distortion of the EEG signal by the cardio-ballistic artefact. Study 1 aimed to develop an approach to restore meaningful physiological EEG data from recordings at different magnetic fields up to 9.4 T. An artefact rejection method was presented that is based on the combination of independent component analysis (ICA) and mutual information (MI). The developed approach consisted of four consecutive steps: (i) ICA was used to decompose the EEG data into independent components (ICs); (ii) mutual information (MI) between the electrocardiogram (ECG) signal and all ICs was calculated; (iii) artefactual ICs were identified by means of an MI threshold; and (iv) the EEG signal was reconstructed using only non-artefactual ICs. The artefact rejection performance was evaluated using EEG data recorded with two experimental paradigms at different magnetic field strengths up to 9.4 T: (i) spontaneous activity using an eyes-open/eyes-closed alternation, and (ii) responses to auditory stimuli, i.e., auditory evoked potentials. The results of this study demonstrated that even at ultra-high magnetic fields up to 9.4 T the proposed artefact rejection approach restored the physiological time-frequency information. Thus, the cleaned data were suitable for subsequent analyses. Moreover, the

results of this study demonstrated that EEG data recorded at ultra-high magnetic fields can be used for studying neuroscientific research question related to oscillatory brain activity.

Study 2 investigated the feasibility of recording MEG data during deep brain stimulation (DBS), an effective treatment for advanced Parkinson's disease. Recording brain activity during DBS using MEG can potentially help clarifying the neurophysiological mechanism of DBS. The DBS artefact, however, distorts MEG data significantly. This study characterized the DBS-related artefacts and subsequently presented an artefact rejection approach based on the combination of ICA and mutual information as in study 1. A reference signal recorded via a surface electrode attached above the DBS cable was used to identify artefactual components. This approach was applied to clean MEG data from five Parkinson's disease patients with implanted DBS stimulators. MEG was recorded with DBS ON (unilateral stimulation of the subthalamic nucleus (STN)) and DBS OFF during two experimental conditions: a visual attention task and alternating right and left median nerve stimulation. The results of this study showed that most of the artefact could be removed with the presented artefact rejection approach. Furthermore, the signal of interest could be retrieved in both conditions. Therefore, the DBS artefact can be significantly rejected and the physiological data can be restored using the presented method.

Study 3 assessed the effects of high frequency DBS on the modulation of cortical oscillatory activity. Previous studies have shown that DBS attenuates oscillatory power in the *alpha* band (8-12 Hz) locally in the STN area and also decrease inter-regional coherency between cortex and STN in the *beta* frequency band. So far, few studies have worked on the effects of DBS on cortical neuronal activity due to the artefact difficulties arising from DBS hardware. The current study focused on the cortical oscillatory changes during DBS. To this end, 17 patients were investigated in this study. MEG was recorded during DBS OFF and DBS ON at two different stimulation frequencies, i.e., 130 Hz and 340 Hz. The artefact rejection method presented in study 2 successfully removed DBS distortions from the MEG signal. Results of this study demonstrated that unilateral DBS is accompanied by *alpha/beta* (8-22 Hz) power suppression over bilateral sensorimotor cortices which support the hypothesis that DBS might affect activity within the entire thalamo-cortical loop. Surprisingly, no difference was found between different stimulation frequencies. Moreover, no significant correlation was found between DBS-induced *alpha/beta* suppression and the associated motor improvement.

In summary, the present studies investigated the feasibility of recording neurophysiological information at the presence of strong artefactual sources such as ultra-high magnetic fields of a MR scanner or DBS. The results demonstrated that using the proposed artefact rejection approach permits to retrieve neurophysiological information. This method can be applied to EEG and MEG data to facilitate research addressing the impact of DBS on brain activity. It can also be used in experimental paradigms that demand the challenging combination of different imaging techniques in order to obtain both high temporal and high spatial resolution.