Recording of Ultrafast (600-Hz) EEG Oscillations with Amplitudes in the Nanovolt Range during fMRI- Acquisition Periods

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Introduction

We are pursuing a noninvasive approach for the recording of electrical correlates of spikes and synaptic activity by means of Electroencephalography (EEG) during MRI. For a truly continuous and simultaneous EEG and MR recording, the MR acquisition periods represent a particular challenge since they induce high-amplitude artifacts within a broad spectral range of the EEG signal mainly caused by gradient switching of the MR-tomograph. Artifact averaging and subsequent template subtraction is commonly used for artifact correction (1). However due the time-variance of the MR-related EEG artifacts residual artifacts, particularly in the spectral range above 40 Hz, persist in the EEG signal.

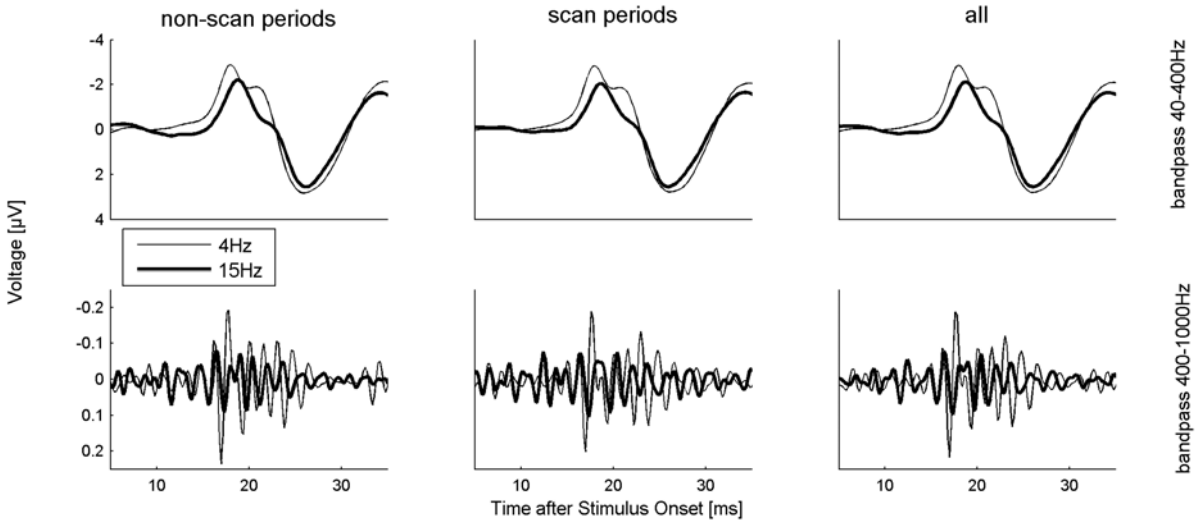
When stimulating peripheral nerves somatosensory evoked potentials (SEPs) can be derived by EEG from the scalp over the contralateral hemisphere. Superimposed on the primary cortical N-20 component is a high frequency burst oscillating at about 600 Hz with amplitudes in the range of 200 nV (2). Simultaneous epiduaral and microelectrode recordings in monkeys have provided strong evidence that these high frequency oscillations (HFOs) reflect compound action potentials in the primary somatosensory cortex (3). A characteristic feature of HFOs is its amplitude dependence on the stimulus repetition rate (4). Objective of this study was the truly simultaneous acquisition of HFOs (presumably correlates of spiking), low-frequency SEPs (correlates of synaptic activity) and the vascular MR responses to median nerve stimulation. As a quality measure we tested whether the subtle amplitude variations in the range of 50 nV due to different stimulus repetition rates can be resolved.

Methods

Simultaneous EEG (Brain Products, Munich, Germany, 5 kHz sampling rate, 32 channels, referenced against a point between Cz and Fz) and fMRI (1.5 T Siemens, Erlangen, Germany) was obtained in 3 healthy subjects (m 26y, f 30y, f 27y). As proposed by Anami and his colleagues (5) we synchronized the MR-tomograph with the EEG-device using a frequency devider (DC-5, Physio Tech, Tokyo, Japan) to obtain time invariant MR-related EEG-artifacts and additionally employed a MR "steppingstone" sequence which was specifically developed by Anami et al. for artifact minimization during simultaneous EEG-fMRI acquisition. SEPs were evoked by conventional electrical stimulation of the right median nerve (repetition rates: 4 and 15Hz, 50% above motor threshold). Per subject 735 MR scans (TR: 3.6 s, TA: 1.8 s, 20 slices, voxel size 3x3x5mm) were acquired. Offline artifact correction (1) and EEG analysis were performed. EEG of channel C-3 was segmented over a 60ms (10ms pre-, 40ms post-stimulus) period, baseline-corrected and selectively averaged for the 4-Hz and 15-Hz stimulus repetition rates. Digital bandpass filtering was performed for the identification of high and low frequency components (400-1000Hz and 40-400Hz, respectively).

Results

In all three subjects HFOs were relyably reconstructed from scan acquisition periods after artifact correction for both stimulation conditions (4hz and 15hz). Stimulus-repetition-rate associated amplitude modulations of the HFOs in the range of 50 nV were clearly identifiable. HFOs obtained from scan periods were in high concordance with those obtained from artifact-free non-scan periods.



Discussion/Conclusions

Synchronization between EEG and MRI as proposed by Anami et al. significantly improves EEG signal quality after artifact correction. Thus, the *continuous* acquisition of high frequency EEG signals possibly reflecting spike activity is feasible during simultaneous fMRI. Even subtle amplitude modulations in the nanovolt range can be resolved.

Acknowledgements /References

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