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Simultaneous multimodal acquisition of surface-EMG, EEG and fMRI

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Introduction

Simultaneous acquisition of surface-EMG, EEG and fMRI is critical for many scientific as well as clinical issues. However simultaneous acquisition of these three modalities is challenging due to strong MR related artifacts in EMG and EEG signals.

Here we show a setup which enables to:

(1) investigate fMRI correlates of neuronal task-related activity measured by EEG and

(2) to correlate fMRI-signal to motor-output, i.e. a real behavioural measure instead of the paradigm.

Additionally, the relation of muscle activity (EMG), neuronal activity (EEG) and metabolic changes (BOLD signal) can be determined with this approach.

Simultaneous monitoring of EMG and fMRI in studies involving the motor system guaranties a better control of subject performance.

The combination of EMG and fMRI is also relevant in research on CNS diseases involving motor function, e.g. blepharospasm [1].

Additionally, the multimodal approach is a prerequisite for vigilance monitoring (based on EEG and EMG of chin electodes [2]) during fMRI.

Continuous EEG-fMRI has been established before [3, 5]. Simultaneous EMG-fMRI has been reported, however EMG data acquisition was restricted to interscan intervals [4]. Here we employed the combination of three modalities - EEG, EMG and fMRI – with continuous data acquisition.

We applied a simple motor experiment to show the feasibility of simultaneous EEG-EMG-fMRI recordings.

Objective was to find fMRI-correlates of the task function, as well as the arm-EMG and of the EEG-mu-rhythm recorded over left motor area (C3). The mu-rhythm, consisting of 10- and 20-Hz components, is functionally connected to the sensorimotor system and is suppressed during hand movements.

Methods

MRI and EEG devices: For fMRI we used an 1.5 tesla (Siemens, Vision) Scanner. MR repetion time was 2.5 s. Acquisition time for 20 slices was 2.2 s.

EEG and EMG were recorded using a modified 32-channel EEG-cap including four EMG electrodes (Easy cap, Falk Minow Services) and a MR-compatible EEG amplifier (Brain Products) with a large dynamic range to capture both low-amplitude EEG/EMG and large MR-artifacts. Sampling frequency was 5000 Hz.

Task

Subjects were lying in the MR scanner and were acoustically triggered to perform a blocked hand movement vs. rest paradigm, each condition 20 s; 12 cycles (schema, a)

Analysis

Functional MR-images were calculated using three different approaches (see schema). Crosscorrelation of fMRI-BOLD signal data with:

(A) EEG information: Mu rhythm desynchronisation was used as a direct neuronal measure of hand movement. EEG signal of electrode C3 was MR artifact corrected (b) [5] and wavelet transformed (c). Resulting spectrum was averaged over the mu-rhythm frequency band 8-12 Hz (d) and then convolved with the hemodynamic response function (f) to take hemodynamic coupling into account.

(B) EMG information as a direct measure of muscle activity: EMG signal of left arm electrode was MR artifact corrected (b) and wavelet analysed (c). Spectrum was averaged over 1-5 Hz band (d) and convolved with the hemodynamic response function (e).

(C) prior task information: hand movement function (a) was convolved with the hemodynamic response function (e).

Resulting regressors were crosscorrelated with fMRI BOLD signal by SPM v2 (f) for all three approaches.

Results

EMG:

Periods of rest were clearly separated from those of movement by the applied artifact removal algorithm (schema, track B).

Functional MR-maps:

For all three approaches somatomotor areas S1, M1 and SMA are clearly visible at significance threshold $p<0.05$ FWE corrected. Correlation is similar for task information and EMG regressor. With the EEG-regressor less significant modulations of the BOLD-response are found in the same areas indicating that mu-rhythm can substitute for paradigm information, however with loss of statistical power, probably due to high EEG-noise. Note that Mu rhythm is inversly correlated with hand movement, resulting in inverse BOLD-modulation (Blue color indicates "deactivations" with mu rhythm.)

Discussion

This is the first study in which fMRI, EEG and EMG are performed simultaneously and in a continuous fashion by means of an apropriate MR-artifact correction. The feasibility of simultaneous monitoring of these three modalities opens new perspectives for research on the motor system, vigilance and motor disease.

It should be noted, however, that the template based MR-artifact removal fails unavoidably when electrodes are moved to strong inducing different MR artifacts in the EMG signal.

Here we show fMRI correlates of somatomotor system can be identified with (A) EEG as a direct measure of neural activation, (B) EMG as a direct measure for muscle activity, and (C) classical pior task information as well.

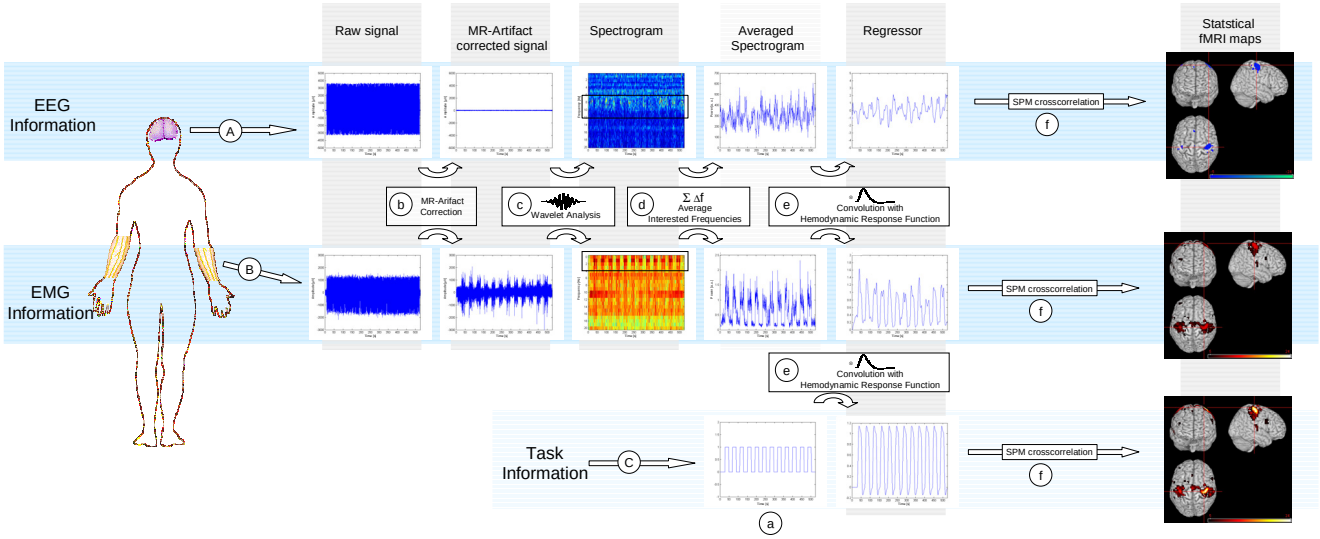

Figure: Functional MR-images were calculated using three different approaches. See Methods Analysis section for details.

Abbreviations

BOLD Blood Oxygen Level Dependent
EEG Electroencephalography
EMG Elektromyography
FWE Family-wise Error
S1 Primary Somatosensory Area
M1 Primary Motor Area
SMA Secondary Motor Area
SPM Statistical Parametric Mapping

References

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