Simultaneous multimodal acquisition of surface-EMG, EEG and fMRI

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Introduction

Simultaneous acquisition of surface-EMG (Elektromyography), EEG and fMRI is critical for many scientific as well as clinical issues. For example it is a prerequisite for vigilance monitoring during fMRI measurements. Since vigilance is continuously fluctuating and since it is known to modulate cerebral neuronal activity, it may be an important confounding factor in many fMRI studies. This becomes relevant especially for studies investigating more subtle changes in neuronal activity or vascular response. Only by the inclusion of vigilance as one more explaining variable, those subtle changes will become statistically relevant. Another important need for especially EMG during fMRI are studies involving the motor system. Monitoring of muscle activity guaranties a better control of subject performance. Additionally the combination of EMG and fMRI will be relevant in research on CNS diseases involving motor function, e.g. blepharospasm (4). Continuous EEG-fMRI was established in our group before (3). Simultaneous EMG-fMRI has been reported before, however EMG data acquisition was restricted to interscan intervals (2). Here we first employed the combination of three modalities - EEG, EMG and fMRI – with continuous data acquisition.

Methods

For fMRI we used a 1.5 tesla (Siemens, Vision) Scanner. EEG and EMG were recorded using a modified 32-channel EEG-cap including six 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. MR artifact correction was performed by a simplified version of an algorithm proposed by Allen et al. (1, see formula): A template (B_n) was calculated by a weighted (w) sum of k adjacent artifacts. This template was then subtracted from the actual contaminated interval A_n. We used Vision Analyzer software (Brain Products) that averages all artifacts weighted with w=1 to calculate one template B, that was subtracted from each artifact contaminated interval A_n.

Results

Muscle activity of chin and both arms (M. flexor digitorum superficialis) during a hand movement block-paradigm was continuously monitored. The applied artifact removal algorithm proofed to be sufficient to clearly separate periods of muscle rest from those of movement. Figure A shows the uncorrected EEG and EMG-signal. In figure B the same signals after artifact correction are shown.

$$B_n = \frac{\sum_{i=0}^{k} w^i A_{n-i}}{\sum_{i=0}^{k} w^i} \quad ; \quad C_n = A_n - B_n$$

Formula: Algorithm for artifact removal
A_n: Artifact contaminated intervals
B_n: Template
w: Weighting factor
k: Number of averaged artifacts

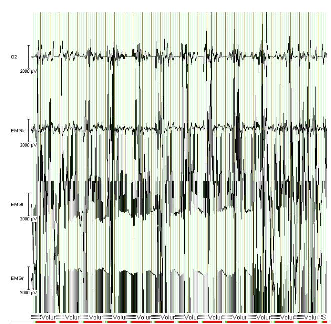

Figure A: uncorrected EEG/EMG

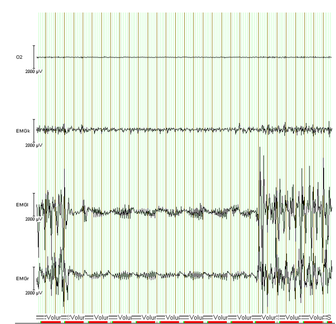

Figure B: artifact corrected EEG/EMG

Conclusions

To our knowledge this is the first study in which fMRI, EEG and EMG of chin- and extremity-muscle activity are performed simultaneously and in a continuous fashion. The feasibility of simultaneous monitoring of these three modalities opens new perspectives for research on the motor system, vigilance and motor disease. However it should be noted that the template based MR-artifact removal fails unavoidably when electrodes are moved to strong inducing different MR artifacts in the EMG signal.

References

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