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*Published in:*
Proceedings of the COST Action workshop NeuroMath

*Publication date:*
2007

NeuroMath
Advanced Methods for the Estimation of Human Brain Activity and Connectivity

# Study of ballistocardiogram artifacts in simultaneous EEG-fMRI acquisitions

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***Abstract.*** The simultaneous acquisition of EEG and fMRI data is very promising for the study of cognitive processes and disorders but causes severe artifacts in the EEG. In this study the aim is to remove the ballistocardiogram artifact, caused by pulse-related movements of the electrodes in the magnetic field. For this purpose a method based on blind source separation with SOBI was used and compared with OBS, a method based on channel-wise template subtraction. To validate the accuracy of the removal, an experiment that evokes visually evoked potentials was performed. Both methods were valuable but the same quality as in measurements without magnetic field could not be achieved.

*Keywords:* Visually Evoked Potentials (VEPs), EEG, fMRI, ballistocardiogram artifacts, SOBI

## 1. Introduction

Simultaneous acquisition of electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) is a promising method in the study of cerebral dynamics. The complementarity between the high temporal resolution of EEG and the high spatial resolution of fMRI can provide a better understanding of brain function and dysfunction. However, when acquired in the MR scanner, EEG data are highly contaminated with two major artifacts. Firstly, gradient artifacts occur because of the switching of the magnetic fields during fMRI acquisition. These artifacts can have amplitudes 10 to 100 times larger than those of EEG signals. In addition to this, ballistocardiogram (BCG) artifacts appear, caused by the pulse-related movement of the scalp electrodes inside the magnetic field. This study will focus on the characteristics of the BCG artifact and on its removal. The quality of the removal will be validated with visually evoked potentials (VEPs).

## 2. Material and Methods

### 2.1. Data acquisition

Because the focus in this study is on BCG artifacts, the measurements were restricted to EEG data without acquiring fMRI. For validation purposes the EEG data were not only acquired inside the static magnetic field of the scanner, but also outside the scanner room. A visual detection task was performed with segments of circular black-and-white checkerboard stimuli presented one at a time in randomized sequences to one of the four quadrants of the visual field or centrally. This task was selected because it evokes a robust P1 component useful for validating the artifact removal. The P1 component is a positive deflection in the VEP around 100 ms after the stimulus onset.

### 2.2. Characteristics of the BCG artifact

In a first part of the study the aim was to learn about temporal, spatial and spectral behaviour of the BCG artifact. The study of temporal characteristics reveals that the artifact's shape and amplitude can differ between different channels and that the amplitude can even change a little over time. Between different subjects the artifact pattern can be completely different. The potential distribution clearly indicates that the BCG artifact has an opposite polarity at the two sides of the head. The influence of the artifact is more pronounced in lateral channels. In the frequency spectrum the artifact causes a peak at the heart rate frequency and at several harmonics.

### 2.3. Artifact removal

Blind source separation is a signal processing technique that can be used to recover independent sources from a set of simultaneously recorded signals that results from a linear mixing of the source signals. In [Mantini et al., 2007] the fastICA algorithm was already successfully used to remove BCG artifacts for clinical studies based on EEG/fMRI integration. In [Niazy et al., 2005] the Optimal Basis Set (OBS) method is proposed for the same purpose. OBS is based on the channel-wise subtraction of a BCG template, created with principal component analysis on all QRS epochs of each channel.

In this study Second Order Blind Identification (SOBI) [Belouchrani et al., 1997] is used to separate BCG artifacts from VEPs. After applying SOBI the artifact-related components need to be selected and the EEG data are reconstructed without these components. The selection procedure is based on computing the correlation between the sources and a certain template. After this an appropiate threshold on this correlation must be chosen to discriminate between BCG and VEP related components. As a template both the ECG channel and a BCG signal were used, whereof the BCG signal was created by concatenating averaged QRS epochs.

The results of SOBI are validated and compared with those of the OBS method. A first criterium is the residual artifact after removal. This is characterized with the peak-to-peak amplitude of the signals created by epoching on the QRS peaks. Also the presence of peaks at harmonics of the heart rate frequency is verified. The recovery of the VEPs of interest can be validated by comparing the results with and without magnetic field.

## 3. Results

Both the OBS and the SOBI method result in a significant reduction of the peak-to-peak amplitude of the averaged QRS epochs. In the frequency spectrum the peaks at the harmonics of the heart rate frequency are reduced with the SOBI method and completely removed with the OBS method. The presence of the peaks for SOBI might indicate that some residual BCG artifact is still present. The VEPs are for both methods of a much lower quality than in the situation without magnetic field. Nevertheless some small P1 components are visible in both cases with a distribution that is rather, but not very pronounced, occipital. Although no heart rate related peaks are visible in the frequency spectrum after the OBS method, the VEPs still show some residual artifact.

## 4. Discussion

The removal of the BCG artifact is a complex problem because the artifact pattern depends on the particular electrodes and even more on the measured subject. To assure an accurate validation, an experiment that elicits VEP components was used. These are rather small components which require a very precise artifact removal. The use of SOBI in this application is useful but needs further improvements to achieve VEP components with sufficient quality in every situation. The question rises if VEPs with the same quality as outside the magnetic field can be obtained.

### Acknowledgements

Research supported by GOA-AMBioRICS, CoE EF/05/006 Optimization in Engineering (OPTEC), IDO 05/010 EEG-fMRI, IOF-KP06/11 FunCopt, several PhD/postdoc & fellow grants; Flemish Government (FWO: G.0407.02, G.0360.05, G.0519.06, FWO-G.0321.06, G.0341.07, IWT); IUAP P6/04; BIOPATTERN (FP6-2002-IST 508803), ETUMOUR (FP6-2002-LIFESCIHEALTH 503094), COST Action BM0601 Neuromath, Healthagents (IST–2004–27214), FAST (FP6-MC-RTN-035801) and ESA (Prodex-8 C90242)

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