# Exploring the pulse artefact in EEG recordings at 9.4 T magnetic field

Jorge Arrubla[1], Lukas Breuer[1], Nuno da Silva[1], Jürgen Dammers[1], Irene Neuner[1,2], and N. Jon Shah[1,3]
[1]*Institute of Neuroscience and Medicine - 4, Forschungszentrum Jülich, Jülich, NRW, Germany,* [2]*Department of Psychiatry, Psychotherapy and Psychosomatics, RWTH Aachen University, Aachen, NRW, Germany,* [3]*JARA - Faculty of Medicine, RWTH Aachen University, Aachen, NRW, Germany*

**Target Audience**
The feasibility of recording electroencephalography (EEG) at ultra-high static magnetic fields up to 9.4 T has been recently demonstrated. It is expected that EEG will be incorporated into functional magnetic resonance imaging (fMRI) studies at 9.4 T. These results are of significant interest to the fMRI and EEG community.

**Purpose**
EEG recordings at ultra-high magnetic fields pose the problem of the pulse artefact. The pulse artefact is produced by cardiac pulse-related movement of the scalp electrodes inside the magnetic field, and the induced Hall-effect caused by movement of blood, an electro-conductive fluid. The fact that the amplitude of the pulse artefact is proportional to the strength of the magnetic field in which EEG is recorded is well described[1,2]. In this study we investigate the components of the pulse artefact in EEG data recorded in a 9.4 T magnetic field.

**Methods**
Resting-state EEG data were recorded from 5 healthy male volunteers (mean age 28.4 years old) inside a 9.4 T human whole-body MR scanner (Siemens, Erlangen, Germany). EEG data were recorded using Brain Vision Recorder (Brain Products, Gilching, Germany) and a 32-channel MR compatible EEG system. Additional electrocardiography (ECG) signals and photopletismogram (PPG) were recorded wirelessly during the EEG acquisition using a physiologic monitoring unit (Siemens, Erlangen, Germany).
Data analysis included detection of heartbeat events in ECG and PPG signals, calculation of the pulse artefact amplitude and Independent Component Analysis (ICA). The amplitude of the pulse artefact was measured by calculating the largest amplitude difference of EEG data around the R-peaks.
Peak detection was performed on the wirelessly recorded PPG and ECG signals, as well as on the ECG signal recorded with the EEG-system.
ICA was performed using FastICA[3], followed by clustering of the independents components (ICs) using ICASSO[4] (http://research.ics.aalto.fi/ica/icasso/). Cross trial phase statistics (CTPS)[5] permitted the identification of ICs related to the pulse artefact, i.e. ICs which were phase-locked to the P-wave, the QRS-complex and the T-wave, respectively. A peak from -0.2 to -0.05 s was identified as being related to the P-wave, from -0.05 to 0.05 as being related to the QRS-complex and 0.05 to 0.3 s as being related to the T-wave.

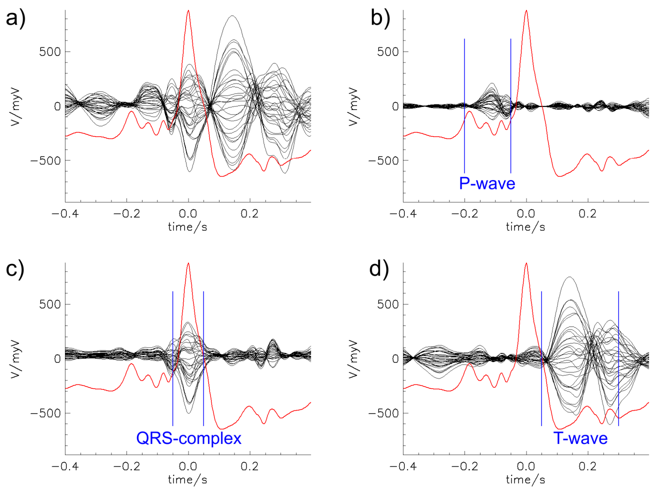


*Figure 1. EEG signal of all volunteers (black) averaged with respect to the R-peak of the ECG signals (red). An average of the whole EEG signal is shown in (a). In (b), (c) and (d) are presented the EEG signals reconstructed from the ICs identified as being related to the P-wave, QRS-complex and T-wave respectively.*

**Results**
The most statistically significant ICs were successfully extracted from EEG data recorded at 9.4 T after applying ICA and ICASSO. The averaged EEG signals across all volunteers and averaged around the R-peaks are presented in Figure 1. It was possible to identify ICs related to the P-wave, the QRS-complex and the T-wave. Interestingly, the contribution of the P-wave (Fig. 1b) and the QRS-complex (Fig. 1c) to the pulse artefact resulted in one observable peak, while the contribution of the T-wave was separated into two peaks (Fig. 1d).
In our sample of healthy male volunteers, there was a trend for decreased pulse artefact amplitude in older volunteers (correlation coefficient R2 = 0.4842). See Figure 2.

**Discussion**
In this study we investigated the components of the pulse artefact in EEG data recorded at 9.4 T. The pulse artefact could be separated into parts belonging to the phases of the heartbeat: P-wave, the QRS-complex and the T-wave. The fact that the pulse artefact could be separated into the different deflections leads to the assumption that each of these phases contributes differently to the resulting artefact. Interestingly, it was possible to identify a link between the amplitude of the pulse artefact and the age of our volunteers, suggesting that the pulse artefact has a strong dependence on what we hypothesize is the arterial compliance.

**Conclusions**
The pulse artefact can be separated into the different deflections, depending of the heartbeat contraction phase, which contribute differently to the resulting artefact. A trend for a negative correlation between the amplitude of the pulse artefact and age was found.

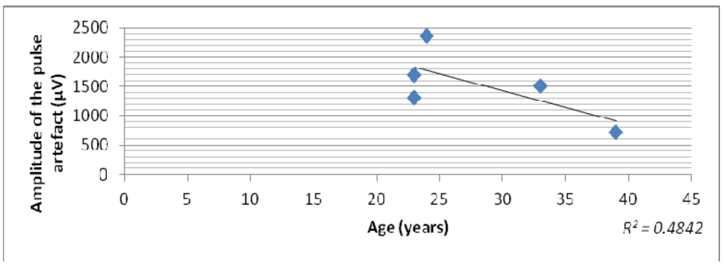


*Figure 2. Amplitude of the pulse artefact in relation to age.*

**References**
[1] Neuner I, et al. Neuroimage 2013;68:214–20.
[2] Debener S, et al. Int. J. Psychophysiol. 2008; 67: 189–99.
[3] Hyvärinen A. IEEE Trans. Neural Netw. 1999;10: 626–34.
[4] Himberg et al. Neuroimage 2004;22:1214–22.
[5] Dammers et al. IEEE Trans. Biomed. Eng. 2008;55:2353–62.