Effects of High Field MR Scanner on Simultaneous EEG Data Quality for Single-Trial Discrimination

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INTRODUCTION:

The emerging technology of recording simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) allows direct comparison of these two very different methods of measuring human brain responses to stimuli. Being able to follow changes in attention, adaptation or habituation on a single trial basis by using single trial EEG data to reveal brain regions which correlate with variations in these should considerably advance our understanding of cognitive processing [1,2]. Simultaneously recorded EEG/fMRI at 3T, presented in this study was of good enough quality to allow these single-trial investigations. Quality Assurance tests [3] confirmed that MR-image quality at 3T, in terms of spatial and temporal SNR, was acceptably stable across time to carry out these studies.

METHODS:

Paradigm: A visual oddball paradigm was applied on a right-handed, healthy, female subject inside Philips Achieva 3T MR scanner. The stimuli consisting of 50% target (face images) and 50% standard (structure images) were presented to the subject via a back-projected screen in a pseudo-random order (ISI between stimuli=2-4 sec). Each stimulus image flashed 50 ms and the subject was asked to response/press the buttons accordingly as seeing either a target and a standard.

Simultaneous Recording: Functional MR images and EEG data were acquired simultaneously at 3T with SENSE head RF coil and single-shot gradient-echo EPI sequence (TR=2000ms, TE=35ms, 64x64x26 matrix, 3.125x3.125x4.5 mm^3 voxels). A multi-path, custom-made EEG cap consisting of 36 Ag/AgCl electrodes was used. The electrodes were designed with 2 or 3 leads for the consideration that the leads from neighboring electrodes could be twisted together and thus minimize the inductive current inside a MR scanner. The head was held on a cushion to reduce the ballistocardigram (BCG) and movement effects. Prior to the experiment, the participant performed a practice block. The EEG data was acquired at the sampling frequency of 1kHz and the analog-to-digital sampling synchronized to the scanner clock with each TR.

Data Analysis: We used a combination of both filtering and average artifact subtraction (AAS) methods to remove the MR artifacts in the EEG. We removed the DC drifting artifact with a 1Hz high pass filter, corrected gradient and pulse effects based on subtracting the average across TR, eliminated the minimal remaining RF artifacts with a 15ms median filter, and then minimizing the power line noises with 60Hz and 120Hz notch filters. AAS has some limitations in removing the BCG artifact due to the variability in cardiac wave duration and shape. We estimated BCG by finding the first 2 or 3 principal components across bipolar EEG channels that were low-pass filtered at 4Hz. The sensor weights derived from PCA were then applied to EEG not filtered at 4 Hz, and this BCG estimate projected into each electrode and subtracted from the data. The power spectrum analysis of the result was computed and compared with those from an auditory oddball experiment conducted at 1.5T (80% target=350Hz tone, 20% standard=500Hz tone, inside 1.5T and outside the scanner) [4] but have the same EEG/fMRI setup and comparable off-line data analyses.

fMRI Quality Control: The scanner instabilities impart some increase in the inter-voxel correlation, presumably because such instabilities result in low-spatial-frequency image correlations. And thus the statistical independence of the voxels may be lost with the increase of ROI size. The EPI data quality was assessed in a parallel experiment applying the Glover stability quality assurance protocol (GSQAP) [3] using a 17-cm-diameter agar gel phantom for seven consecutive weeks (TR/TE: 2000/30ms, FOV:220x220mm, Bandwidth>=100kHz, Matrix: 64x64, dynamics: 198+2 warmups). An analysis due to Weisskoff was conducted to examine the stability of EPI data.

RESULTS:

Figure 1 illustrates the EEG data recorded outside and inside 1.5T and 3T MR scanners. The power of BCG and MR environment artifacts from 1.5T were successfully reduced by 95% and 97% fro 3T; while the energy in alpha band and beta band (significant neural signature frequency range) were mostly kept. The Weisskoff analysis for one week EPI data at 3T is shown in Figure 2. The radius of decorrelation (RDC) shows the size of ROI at which statistical independence of voxels may be lost. In our seven-consecutive-week study, as shown in Figure 2, RDC stays in a reasonably stable range (10.9±1.7 voxels).

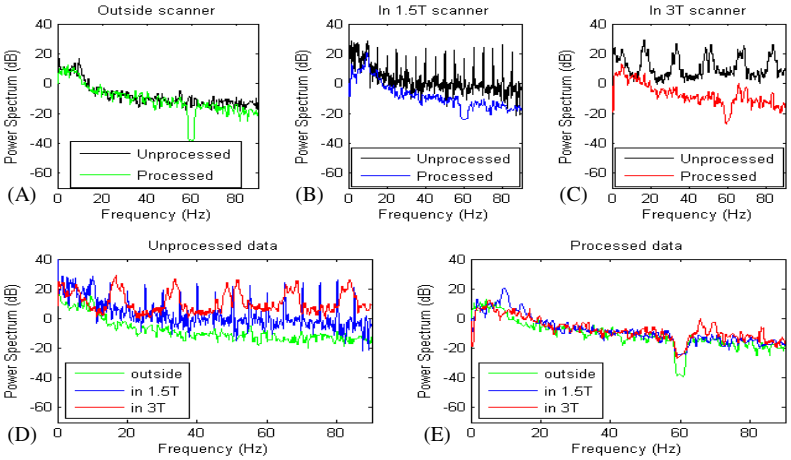
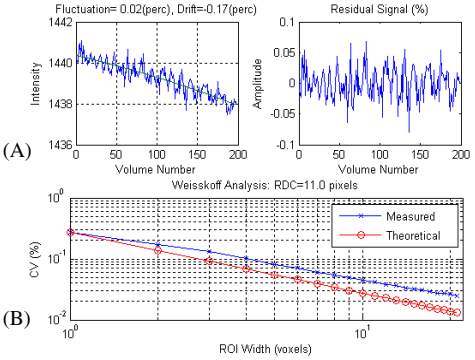


Figure 1. Power Spectrum Density of unprocessed / processed EEG data from (A)outside the scanner, (B)in 1.5T, and (C)in 3T scanner. (D)Unprocessed EEG vs. (E)Processed EEG.



RDC(voxels)	Fluctuation(%)	Drift(%)	SNR
10.94 ± 1.72	0.031 ± 0.005	-0.26 ± 0.14	317 ± 41

(C)

Figure 2. (A)ROI signal detrended with a 2nd order polynomial fit. (B)Weisskoff analysis on week7 EPI data. (C)Summary values across seven weeks (mean ± std.)

CONCLUSIONS:

In our optimized experiment setup and post-processing for simultaneous EEG in high field MR environment (Philips Achieva 3T), the EEG data are of acceptable quality for single-trial neural signature assessment and this variability can be used to better model the latency in the simultaneously acquired BOLD images. The quality control of EPI at 3T is examined very stable across weeks to ensure the validity of neural signal studies.

REFERENCES & ACKNOWLEDGEMENTS:

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