An optimized setup for simultaneous EEG-fMRI at ultra-high field in a head-only 7T scanner

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Target audience: neuroscientists, engineers and clinicians interested in simultaneous EEG-fMRI at ultra-high field.

Purpose: simultaneous EEG-fMRI acquisitions have proved valuable for the study of spontaneous brain activity, but are prone to specific artifacts that can seriously compromise data quality. In particular, mechanically-propagated scanner vibrations, mainly due to the He compression pumps, can produce large EEG artifacts through magnetic induction, with significant impact on recordings performed at ultra-high fields[1]. In this work, we explored the advantages of a head-only MRI scanner for simultaneous EEG-fMRI acquisition, at 7 Tesla, using an optimized EEG setup with short cable lengths (~12cm from cap to amplifiers). The effects of cable length and type on EEG noise sensitivity were assessed, with specific attention to He pump contributions. Following tests on safety and MR image quality, simultaneous EEG-fMRI acquisitions were performed on human subjects under visual stimulation.

Methods: acquisitions were performed on an actively-shielded 7T head scanner (Siemens, Erlangen), equipped with a head gradient set and an 8ch Tx/Rx birdcage head coil (Rapid Biomedical). EEG data were acquired with a custom 64ch cap with short wire braids (EasyCap, Herrsching), connected to two BrainAmp MR Plus amplifiers (Brain Products, Munich) via custom-built ribbon cables. Three studies were conducted:

(1) Ribbon cable noise contributions: the EEG cap was replaced with a signal tester box, which was fixed to the top of a head phantom placed in the scanner. EEG data were acquired without scanning, with the He pumps switched ON or OFF. Different ribbon cable lengths (100/50/12cm), and types (typical flat configuration, or bundled with the wires tightly bunched together, minimizing loop areas along the cable[2]) were tested.

(2) Safety and image quality: using the 12cm bundle-type cables, simultaneous recordings were performed on a head phantom while monitoring temperature fluctuations on the EEG amplifiers and cap. An 8min GRE-EPI sequence (69% SAR limit, TR=2s, α=78°), and an 8min SE-EPI sequence (91% SAR, TR=2.5s, α=90°) were applied. MR image quality was assessed in one human subject, with and without the EEG setup. GRE-EPI (1.5mm isotropic, TR/TE=2000/25ms) and 1mm GRE images were acquired, along with B_0 and B_1 (SA2RAGE[3]) field maps.

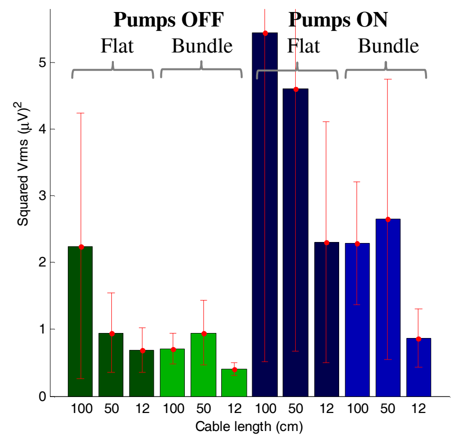

Fig 1. Effects of ribbon cable length and type on EEG noise power.

(3) Functional study: with the optimized setup, simultaneous EEG-fMRI was performed on 5 human subjects under visual stimulation with flashing checkerboards (~4Hz reversal for 10s, followed by 20s rest, 8 repetitions). EEG data were corrected for gradient and pulse artifacts, decomposed with ICA, and trial-averaged. FMRI data were motion-corrected, de-trended, and GLM-analyzed.

Results: **(1)** As shown in Fig. 1, noise power increases with cable length. This comes in agreement with previous reports from a compact setup at 4T[4]. Bundle cables are better protected from induction effects, and at short length become almost insensitive to He pump contributions. **(2)** Over the 16min period of EPI acquisition (GE+SE), only the EEG amplifiers showed noticeable temperature increases (~6°C), still well within their operating range (10–40ºC). No variations were detected on the cap surface, and no recording problems were encountered. MR artifacts were introduced by the EEG system, mainly due to B_1 shielding effects caused by the cap wires (Fig. 2). **(3)** Visually-evoked potentials were detected for all subjects, with varying degrees of SNR, most likely depending on subject motion (example in Fig.3). BOLD data displayed robust signal changes in occipital areas, as expected.

Conclusion: Head-only MR scanners allow for significant reductions in cable length from electrodes to amplifiers, without compromising subject and amplifier safety. Optimization of the EEG signal chain yields valuable improvements in data quality.

References: **(1)** Mullinger K et al. Magn. Reson. Imaging, 2008. **(2)** Chowdhury M et al. ISMRM 2012. **(3)** Eggenschwiler F et al. Magn. Reson. in Medicine, 2012. **(4)** Assecondi S et al. ISMRM 2013.

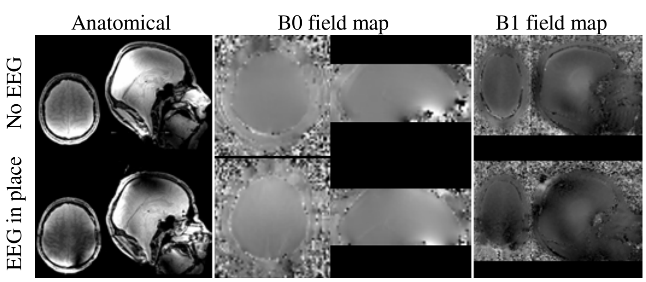

Fig 2. EEG-induced MR image artifacts with the optimized setup.

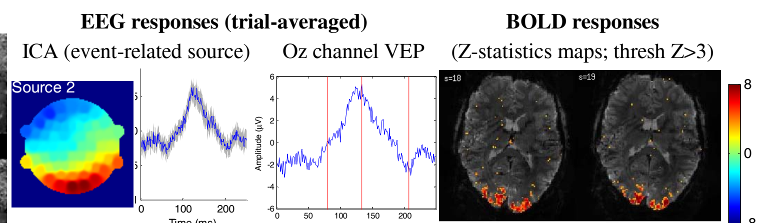

Fig 3. EEG and fMRI responses to visual checkerboard stimulation, in a representative human subject. VEP timecourses are shown with no temporal filtering.