

A compact setup to improve the quality of EEG data recorded during fMRI

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PURPOSE: Despite their potential, simultaneous EEG-fMRI experiments are not yet routinely performed because of technical difficulties and the lack of standardisation of recording and analysis procedures. In this work we describe the experience in our institution with a 4 T MR scanner. In our laboratory EEG quality during concurrent fMRI benefits from a *compact* setup in which the EEG cables are shortened and the amplifiers placed closer to the MR (RX/TX) coil [1] and stabilised on a wooden form-fitting extension moving with the MR bed. We evaluate such setup in terms of data quality [2], and discuss the implications of its use on reproducibility and safety during EEG-fMRI experiments. These considerations are also relevant to higher or lower field strengths and to people setting up their first EEG-fMRI experiment.

METHODS: After having identified the main sources of noise in our laboratory (i.e. the cryogenic pump of the MR-scanner and the ventilation system of the MR-room), we modified the MR-compatible EEG cap and devised a *compact* configuration for the placement of the EEG cables and amplifiers during simultaneous EEG-fMRI. Our setup comprises a form-fitting wooden extension, moving with the MR-bed and the use of an RX/TX MR-coil, open at the back. This configuration allowed us to reduce the length of the EEG cables connecting the cap to the amplifiers, which now fall straight along the z-direction of the bore. The *compact* setup was compared with a *reference* unmodified setup, in which the amplifiers were placed at the back of the magnet bore and stabilised with sand bags. The EEG caps (both

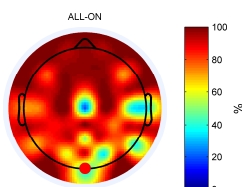


Figure 1 Scalp distribution of the total PSD% reduction in the ALL-ON condition, when the compact setup is used instead of the reference.

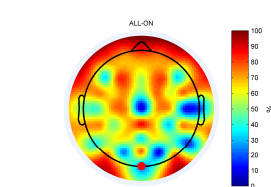


Figure 2 Scalp distribution of the RMS reduction in the ALL-ON condition when the compact setup is used instead of the reference.

spectral density (PSD) in the *compact* with respect to the *reference* setup (calculated as $(PSD_{REF} - PSD_{CMP}) / PSD_{REF} * 100$) with all PSD values normalized with respect to their corresponding ALL-OFF condition; B) reduction of the variability of the imaging artifact across volumes in the *compact* with respect to the *reference* setup (defined as the root-mean-square (RMS) of the point-by-point standard deviation across volumes, averaged across channels and calculated as $(RMS_{REF} - RMS_{CMP}) / RMS_{REF} * 100$); C) quality of the average ERP waveform, elicited by a visual stimulus, and its scalp distribution at the latency of the P100 component, in two subjects. We found that the *compact setup* heavily reduced the total power contribution of the noise sources with respect to the *reference* setup (average PSD reduction: $84 \pm 19\%$, see Figure 1 for its scalp distribution). The *compact* setup also reduced the variability of the imaging artefact (average RMS reduction: $60 \pm 21\%$, regardless the condition, see Figure 2 for its scalp distribution). While the topography of the P100 (Figure 3, upper row) showed no differences between the *compact* and the *reference* setup, we found a higher P100 amplitude (at the Oz channel), in the *compact* setup, consistently across subjects, in both conditions (Figure 3, lower row).

DISCUSSION: We found that shortening the EEG cables and stabilizing the amplifiers on a bed extension, reduce both the noise in the EEG data due to the MR environment and the variability of the imaging artefact. This is likely to result in a better performance of traditional template-based artefact reduction algorithms and, thus, in better data quality. While the stimulus-locked average waveforms and topographies are in agreement with previous findings [3], the higher amplitude of the P100 suggests a better sensitivity of the *compact* setup, and an improved overall quality (in terms of less artefact contamination) of continuous, non-averaged data. Even though a more thorough evaluation on several tasks and subjects is necessary, this aspect can be particularly relevant to EEG-fMRI, where more informative data integration is obtained by exploiting the single-trial variability. We speculate that the *compact* setup, being more constrained, offers a better reproducibility of cables placement across experiments. Using a wooden form-fitting force-locked extension of the MR-bed, the *compact* configuration also enables an easier disconnection of the EEG equipment from the subject in case of an emergency, thus improving safety. These considerations are also relevant to higher field strengths and to different cognitive protocols.

CONCLUSION: We propose a *compact* setup, featuring a modified EEG cap with a straight routing of shortened EEG cables along the z-axis of the magnet bore that allows placing the MR-compatible amplifiers close to the MR-coil on a form-fitting wooden extension, force-locked to the back of the MR-bed. By evaluating the *compact* setup in terms of EEG signal quality, we found that a careful design of the workplace for EEG-fMRI recordings, tailored to the laboratory-specific needs, not only improves the quality of EEG data achieved during simultaneous EEG-fMRI, but can also impact on important aspects such as safety, ergonomics and reproducibility of the setup across sessions and laboratories. These considerations may be relevant to other laboratories interested in reducing the sensitivity of the experimental setup to external noise sources, as well as researchers setting up their own EEG-fMRI workplace for the first time.

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REFERENCES: [1] D.W. Carmichael et al. NeuroImage, 2012., [2] K. Mullinger et al. Int.J.Psychophysiol, 2008 [3] J.V. Odom et al. Doc.Ophthalmol., 2010.

the standard and the modified one) had 64 electrodes (63 EEG, standard 10-20 arrangement, and 1 ECG) connected to two BrainAmp MRplus amplifier units (Brain Products GmbH, Gilching, Germany). The MR scanner was a 4 T MRI system (MedSpec, Bruker Biospin head scanner with Siemens MAGNETOM electronics) with a birdcage transmit and 8-channel receiver head RF coil (USA Instruments). Functional MRI was acquired using a standard EPI protocol (TE 33 ms, TR 2200 ms, flip angle 75° , 3 mm isotropic voxels, 64×64 matrix, 37 axial AC-PC-oriented slices, slice gap 0.45 mm, 180 volumes). Electrodes impedance was kept below 10kOhm. The FCz electrode was used as reference. EEG recordings were performed with the *compact* and the *reference* setup on a phantom (5 minutes of recording) and on two human subjects during a visual detection task (2 Hz checkerboard) with the noise sources (cryogenic pump and ventilation) either turned on (ALL-ON condition) or off (ALL-OFF condition).

RESULTS: The two setups were compared in terms of: A) reduction of the total power

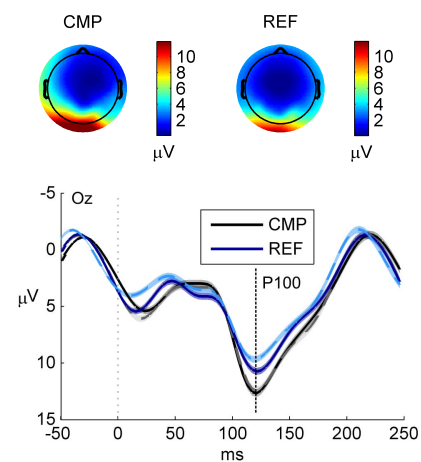


Figure 3 Comparison of average ERP responses (thick line ALL-ON; dashed line ALL-OFF), with the two setups (blue and light blue - compact (CMP); black and gray - reference (REF)) and scalp distributions at P100 latency in the ALL-ON condition.