OPTIMIZED FMRI PULSE SEQUENCE FOR SIMULTANEOUS EEG-FMRI: SPIRAL PSEUDO REAL TIME (SPRETI)
Ana Beatriz Solana1,2, Juan Antonio Hernández-Tamames3,4, José Luis Ortiz1, Elena Molina1, Eva Manzanedo1, Fernando O. Zelaya1, and Francisco del Pozo1
1Center for Biomedical Technology, Pozuelo de Alarcón, Madrid, Spain, 2DBT, Global Research Center, General Electric, Munich, Munich, Germany, 3University Rey Juan Carlos, Madrid, Spain, 4Fundación Reina Sofia, Madrid, Spain, 5King’s College London, London, United Kingdom

Target audience: Physicists, psychologists and clinicians interested in the combination of MRI and electrophysiological signals.

Purpose: Simultaneous EEG-fMRI is challenging mainly due to the artifacts induced in the EEG by the MR gradients. EEG gradient-induced artifact (GA) is the most disturbing artifact in this multimodal technique1. GA depends on the characteristics of the fMRI pulse sequence: EPI and spiral are the most common fMRI readout techniques. GA is higher in spiral scanning2 and explained due to the chirping spectrum of the spiral trajectory2 and by the use of larger crusher gradients at the end of the readout1. One of the key applications of EEG-fMRI is study of epilepsy3. In these studies it is generally required whole brain coverage and taking into account that the scan could be manually stopped due to seizures in the patient. In this work, we present a new spiral fMRI pulse sequence, “Spiral pseudo Real Time (SpRETI)” with key features that make it suitable for simultaneous EEG-fMRI including: 1) the generation of reduced EEG GA using reduced slew rate and amplitude gradients; 2) real time data storage directly in the MR console; and, 3) B0map calculation including two initial volumes with different TE (independent on the fMRI parameters). The performance of SpRETI was validated using EEG gradient-induced artifact characteristics, and its removal, and the BOLD contrast in motor and visual tasks. Results were compared with EPI and other spiral fMRI pulse sequences.

Methods: Phantom: EEG cap was placed on a spherical water phantom previously covered with electrolytic paste. Subjects: Two healthy subjects (mean age 26±1 years) participated in this study.

Data acquisition: EEG data were recorded using a Brain Products MR compatible system using a synchronization setup3. MRI data were collected using a General Electric Signa 3.0 T MR Scanner. Four different 2D gradient-echo fMRI psds were used: GE-EPI, GE–SPRLIO (spiral in-out) GE–SPEP (spiral out) and GE-SpRETI (spiral out). BOLD fMRI parameters for all the sequences were: TR/TE/voxel dimensions/slices = 2.888/25ms/5.3x3.4x3.4mm, 36. Stimuli and experiment: The volunteers performed two tasks: First, a block-design motor task of 40 seconds cycle with 20 seconds of right hand grabbing movement and 20 seconds of rest (5 cycles). This task was repeated for GE-EPI, GE–SPRLIO, GE–SPEP and GE-SpRETI. Second, a mixed event-related block-design visual task with 62 seconds cycles: 12 neutral images were presented with randomized interval fitting in 42 seconds and 20 seconds rest (5 cycles). This task was repeated only for GE-EPI, GE–SPRLIO, GE–SPEP and GE-SpRETI. Second, a mixed event-related block-design visual task with 62 second cycles: 12 neutral images were presented with randomized interval fitting in 42 seconds and 20 seconds rest (5 cycles). This task was repeated only for GE-EPI, GE–SPRLIO, GE–SPEP and GE–SpRETI. Second, a mixed event-related block-design visual task with 62 seconds cycles: 12 neutral images were presented with randomized interval fitting in 42 seconds and 20 seconds rest (5 cycles). This task was repeated only for GE-SpRETI, GE–SPRLIO and GE–SPEP. Stimuli were presented to each subject independently using FSL. The maximum and minimum Z value, and the percentage of BOLD change (mean of BOLD change per cycle) in the statistical peak voxel were used as quantitative measurements for comparison among the fMRI pulse sequences.

Results: An example of one slice acquisition of the GE–SpRETI profile in physical units with its associated gradient artifact (in the phantom for the worst case EEG channel) is shown in Fig. 1A. EEG VSDs before AAS correction for all sequences are shown in Fig. 1B. SpRETI generated the lowest VSD peaks in the slice frequency and harmonics. Fig. 1C shows the gain values from the corrected EEG epochs of all the pulse sequences with respect to the background noise for the slice frequency and harmonics for the phantom data. Last, Fig. 1D shows the Euclidean distance from the corrected EEG VSDs to the background noise VSD. On the other hand, Fig. 1E and Fig. 1F shows the results of the motor task and the visual task fMRI analyses, respectively. The spatial statistical map (FWE, p<0.05) and the BOLD time course response in the most significant voxel for volunteer 1 using GE-SpRETI are shown an example for each task. Additionally, the comparison quantitative measurements are summarized using bar plots. Results with GE–SpRETI were equivalent or superior to the rest of fMRI for both volunteers and tasks.

Discussion: GE–SpRETI has shown optimal characteristics for simultaneous EEG-fMRI. A good performance in the motor and visual fMRI tasks and the lowest distortions associated to the gradient-induced artifact compared to GE-EPI and other spiral pulse sequences. This new fMRI sequences also stores the data in real time and calculates B0map within the same acquisition. All these features made this sequence optimal for simultaneous EEG-fMRI including epilepsy studies.


Figure 1: A-D: Results from the EEG gradient-induced artifact comparisons. E-F: Results from the fMRI comparisons for motor and visual task, respectively.