Automated and Individualized fMRI Processing for Pre-surgical Mapping: Comparison with MEG and Cortical Stimulation.

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Target Audience: Researchers and clinicians doing individual level functional MRI pre-surgical mapping.

Purpose: Functional MRI (fMRI) is frequently employed for pre-surgical mapping. One of the challenges in implementing fMRI clinically is that the best processing choices vary between individuals, requiring an expert to make appropriate data processing choices. While the same processing challenges exist for magnetoencephalography (MEG), it is a more direct measure of neural activity, which may confer an advantage for pre-surgical mapping. We have developed a method for automatic individualized processing of pre-surgical mapping using the ROC-r framework [1]. This method optimizes both pre-processing pipelines and activation thresholds on a case-by-case basis. We compare pipeline optimization and localization obtained for fMRI with MEG in a group of typical volunteers, and additionally with the gold standards of intraoperative cortical stimulation (CS) or sensory evoked potentials (SEP) in patients.

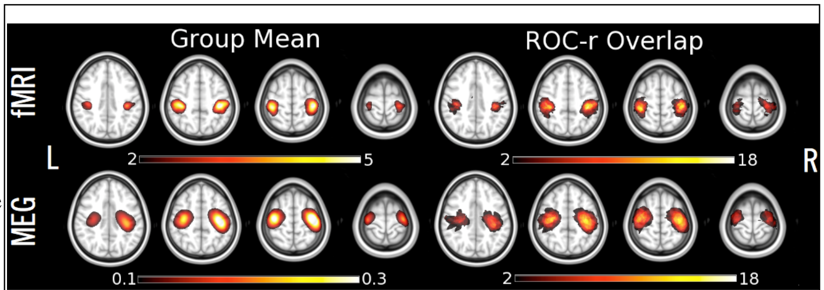

Figure 1: Group-level fMRI and MEG maps (left), compared to overlap of the individual level maps (right). In the majority of subjects (95% for fMRI and 85% for MEG), the automated mapping produced activation of the primary sensory-motor cortex, in the same region as the group average.

Methods: 20 healthy volunteers had both fMRI and MEG scans. Participants performed a combined language/motor task 3 times within each session. In the task, participants decided if 90 pairs of English words were semantically related (50%) or unrelated (50%), and responded by squeezing a grip-force device with the left/right hand respectively. Patient volunteers performed the same pre-surgical task. For these patient volunteers, CS mapping and SEPs were recorded during surgery.

The fMRI data were motion corrected, high-pass filtered, and spatially smoothed prior to statistical analysis. Sixteen fMRI processing pipelines were tested from the possible combinations of: AFNI or FSL software, stimulus or response based model, with/without autocorrelation correction (ACC), and with/without motion parameter regression (MPR).

MEG data were band-pass filtered, down-sampled and averaged prior to computing beamformer source maps. Head models were created in Freesurfer for boundary element method forward solution calculations. Eight MEG pipelines were tested, including: MNE or Neuromag beamformer, averaging to EMG or grip force onset, and with/without independent component analysis (ICA) denoising.

ROC-r was used to optimize data processing options (i.e. by choosing the option with the highest reliability score). The final activation map (averaged between the three runs) was thresholded by the automated ROC-r method. For the patient group, the optimized maps were compared to gold standard electrophysiological measures.

Results: The most common optimal pipeline for fMRI was: FSL software using the response model with ACC, and no MPR. For MEG, the most common optimal pipeline was: Neuromag beamformer with grip force onset averaging, and no ICA denoising.

Automated thresholding of the activation maps was successful in 19/20 individuals for fMRI and 17/20 for MEG. The activation detected in both cases was consistently located around the pre- and post-central gyri in the region of the hand knob. The fMRI activity was posterior and superior to the MEG activation on average, although this was not the case in all subjects. Figure 1 shows that areas identified in the single-subject maps coincided with areas demonstrating significant group-level activity.

The patient cases confirmed the pre-surgically mapped hand motor regions by both sensory evoked cortical potentials and cortical stimulation evoked EMG activity (e.g. figure 2).

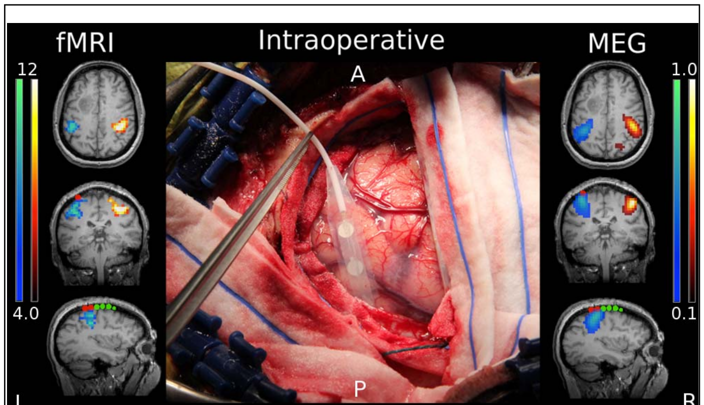

Figure 2: Patient example of a left superior frontal lobe tumour. Cortical stimulation between subdural electrodes 1 and 2 (red dots) produced EMG activity in the right hand. Right median nerve stimulation induced phase reversal between the same electrodes. The fMRI and MEG activity was produced automatically, using optimized processing pipelines, without user intervention. The automated production of highly concordant results between fMRI, MEG, CS, and ECoG has clear clinical benefits.

Conclusion: In this study, we demonstrated the potential of automated and individualized fMRI processing for pre-surgical mapping. We confirmed the fMRI results both with MEG and intraoperative electrical stimulation or recordings. Our method enhances clinical fMRI, by reducing the need for expert intervention in the production of activation maps. This allows push-button mapping, with the collected data being automatically processed, optimized, and made ready for reporting by a radiologist.

References: [1] Stevens et al., J. Neurosci. Meth. 219, 312-23.