BOLD mapping of finger movement compares with the underlying electrophysiology; a combined 7T fMRI and ECoG study

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Introduction

A key requirement for the accurate interpretation of BOLD activation is the accurate spatial co-localization of the BOLD signal with the underlying neuronal activation patterns. Several studies, predominantly in primary visual cortex and at high field strength (7T), have shown that BOLD fMRI has the potential to map activation patterns of small scale neuronal ensembles such as cortical columns [1,2,3]. However, to directly confirm whether BOLD activation maps reflect the underlying neuronal activity patterns, a comparison with accompanying neuro-electrophysiological data is required. Here, we investigate the spatial representation of finger movements on sensorimotor cortex using high density electrocorticography (ECoG) grids post-implant and presurgical BOLD fMRI at 7T in the same subjects. Both techniques measure at a similar resolution (1.5 mm), allowing for a direct link between techniques and evaluation of the BOLD spatial specificity in the case of individual finger activations.

Materials and Methods

The subjects had normal hand function and were scheduled for the implantation of ECoG arrays for the clinical purpose of epilepsy monitoring. *Functional paradigm:* two right handed subjects were visually instructed to move their thumb, index, or little finger (right hand) twice in a randomized event-related design: 30 trials/finger, inter-trial interval = 4.4 s, trial duration = 0.5-1 s, and run duration = 6.7 min. A digital dataglove was used to measure finger movements. *Data acquisition:* presurgical BOLD fMRI data were acquired on a Philips 7T system (16-channel head coil) using GE-EPI: TR/TE = 880/27 ms, flip angle = 65°, SENSE factor = 2.5, FOV = 155 × 155 mm^2, and 13 slices on the left sensorimotor cortex (M1 and S1). Large draining vessels were identified using a high-resolution T2*w anatomy scan [4], and were excluded from analysis. *ECoG*; an 8×4-electrode grid (size: 12 x 23 mm^2) was placed over sensorimotor area (3 mm pitch) and subjects performed the same motor task while ECoG was recorded (512 Hz). Next, z-score timecourses were obtained for the ECoG power in the high frequency broadband (65-95 Hz, HFB-power) for each electrode. ECoG electrode locations were converted to the common MRI space (T2*w anatomy scan) using the method by Hermes et al [5]. *Analysis:* Contrast maps for each finger activation where computed for the BOLD and ECoG data, i.e. movement of one finger versus movement of the other two fingers, using the dataglove data as regressors. BOLD finger activation underneath each ECoG electrode was computed as the maximum BOLD z-value in a 5 mm search column underneath each electrode (direction orthogonal to the electrode plane). Next, spatial correlation (Spearman coefficient, R) was used to compare the spatial distribution of finger activation of both techniques.

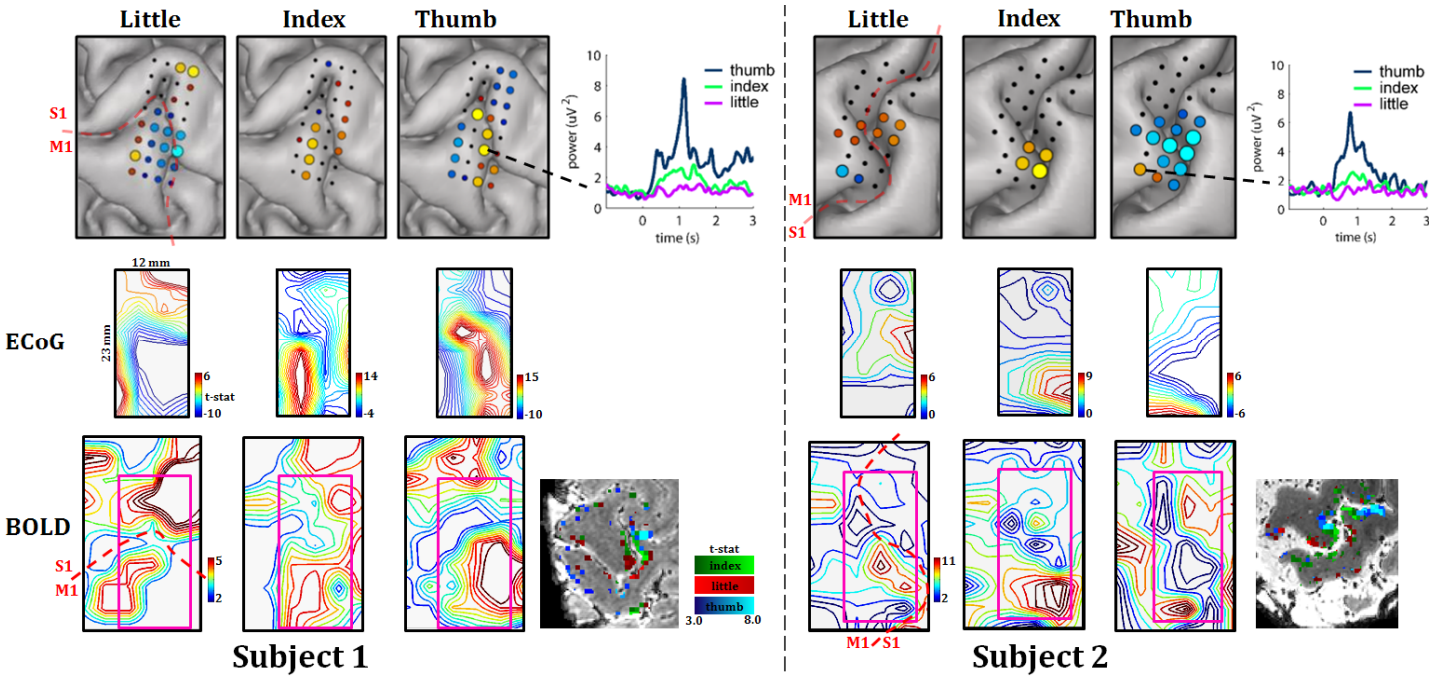

Figure 1. Top row; *the location of the ECoG grid is shown on a 3D rendered brain together with the ECoG contrast maps (t-stats, yellow is high) obtained for each finger for both subjects. The HFB power for a single electrode is also shown, revealing in this case the preference for thumb movement.* ***Middle row****; the same ECoG contrast maps for each finger as in the top row depicted as contour plots.* ***Bottom row****; BOLD contrast maps for each finger underneath the ECoG grid shown as contour plots. The box in magenta illustrates the location of the ECoG grid. BOLD contrast maps for each finger (index in green, little in red, thumb in blue) are also shown on the T2*w anatomy scan for a single slice.*

Results and Discussion

The spatial pattern of the ECOG and BOLD contrast maps for each finger movement (little, index and thumb) are shown in figure 1 for both subjects. Results show that movement of three individual fingers could be distinguished on a spatial span of 12 mm, corresponding to the smallest dimension of the ECoG grid. Both the ECoG and BOLD reveal the same spatial organization of finger activations in M1 for both subjects: activation patterns were organized from little, index, to thumb in neighboring patches of cortex (Figure1; for Subject 1 evident from left to right on the ECoG grid, and for Subject 2 evident from top to bottom on the ECoG grid). The spatial correlations between the spatial pattern of finger movement activation for ECoG and BOLD (underneath the ECoG grid) were R_{index} = 0.76, R_{little} = 0.82, and R_{thumb} = 0.55 (P<0.01) for Subject 1, and R_{index} = 0.71, R_{little} = 0.31, and R_{thumb} = 0.41 (P<0.01) for Subject 2. These values show a high spatial correspondence between ECoG and BOLD activation patterns. The match between modalities however can be subject to remaining ECoG-grid localization errors due to post-implant brain shift and electrode projection on the cortical surface.

Conclusion

The spatial match between ECoG and BOLD fMRI for finger movements is very promising for spatial correspondence between neuronal and vascular responses.
The results show that underneath the electrode grid the BOLD activation patterns are closely related to the ECoG activation patterns in the HFB power.
Future work will investigate the contribution of different ECoG frequency bands in the BOLD spatial patterns, differences between primary motor and sensory activation, and the role of cortical-depth dependency.

References:

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