Spatio-Temporal Response Patterns in Sensorimotor Cortex Using Surface-Based Smoothing of fMRI Data

#1255 MT-AM

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Background

Maximizing the accuracy of fMRI imaging of movement-related Blood Oxygen Level-Dependent (BOLD) responses in motor cortex is a long-standing goal in fMRI research (Sanes et al., 1995). Applying a new surface-based approach of high-resolution fMRI data analysis including manual EPI segmentation and two-dimensional (2D) Gaussian smoothing, we investigated the exact spatiotemporal response pattern of primary sensorimotor cortex in response to a finger movement task.

Methods

FMRI data sets were obtained from ten healthy subjects performing a simple visuomotor task at 3 and 7 Tesla (Siemens, Trio). Sensorimotor cortical layers were segmented manually on initially acquired high-resolution EPI images (Fig. 1). Triangulated surface meshes were generated, and the surface voxels' BOLD responses were extracted and projected onto the meshes. Surface-based spatial smoothing was performed applying a two-dimensional Gaussian filter kernel of 4 mm full width half maximum (FWHM). Hemodynamic time courses of voxels showing significant responses were characterized and spatial activation patterns examined. A comparison with volumetrically (3D) smoothed fMRI data was done using SPM8.

Results

2D-smoothed data show higher amplitudes but fewer significant voxels compared to 3D-smoothed data, as can be seen from the observed HRF time courses (Fig. 3). As a consequence, strong and clearly defined activation patterns can be identified on the surface activation maps (Fig. 4a,b), displaying a high mean peak number of 12.17 ± 1.94 at 1.5 seconds after movement onset (mean over all subjects). In contrast, the high number of low-amplitude activations produced by volumetric smoothing yielded more diffuse activation patterns (Fig. 4b,d).

Conclusion

Standard approaches of fMRI data analysis include volumetric filtering which integrates responses from anatomically separated areas. This can result in false-positive results and sub-optimal spatial accuracy (Andrade et al., 2005; Jo et al., 2007). Surface-based approaches minimize these disadvantages. Additionally, EPI-based cortex segmentation as used in the present study avoids segmentation errors caused by incorrect anatomical-functional co-registration.

In summary, the methods applied in the present study provides a framework to perform more accurate spatio-temporal analyses of response patterns in the human cortex.

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Acknowledgements
This work was supported by the German Federal Ministry of Education and Research (Go-Bio Projekt 0313891)

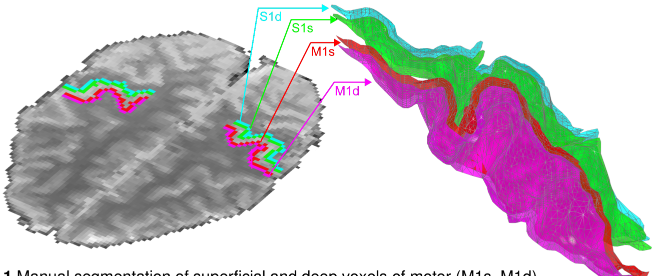

Fig. 1 Manual segmentation of superficial and deep voxels of motor (M1s, M1d) and sensory (S1s, S1d) cortices. Segmentation was performed for each acquired axial plane and marked voxels were assembled to cortical layers

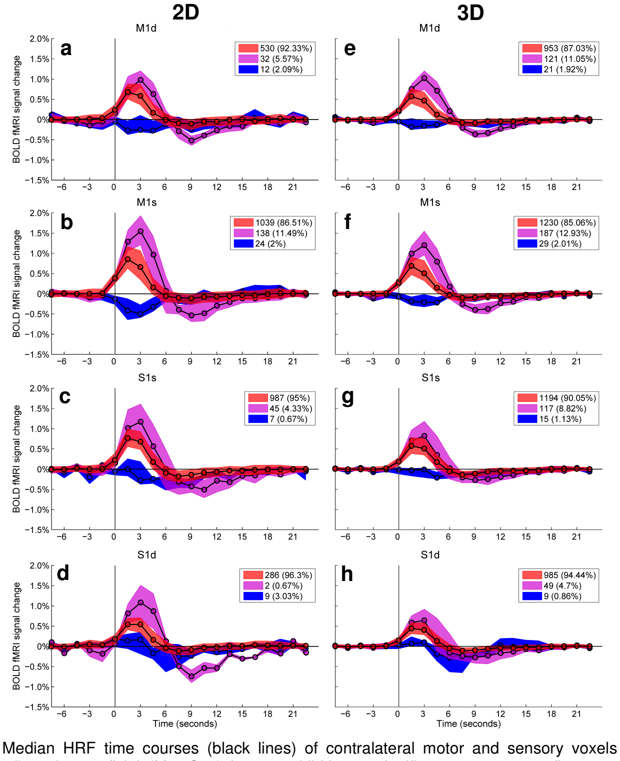

Fig. 2 Median HRF time courses (black lines) of contralateral motor and sensory voxels in deep (M1d,S1d) and superficial (M1s,S1s) layers exhibiting a significant response to finger movement. Vertical lines mark movement onset. a-d: 2D-smoothed data; e-h: 3D-smoothed data., red curves: voxels showing early activation followed by slight undershoot; purple curves: voxels showing biphasic responses; blue curves: voxels showing delayed deactivation. Upper and lower limits of curves mark 75-/25-percentiles. Numbers and percentages of voxels of each type are displayed top right.

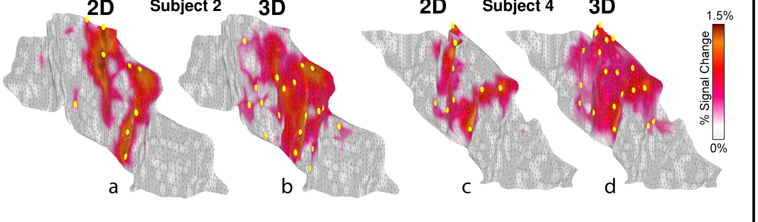

Fig. 3 BOLD activation in the contralateral superficial motor cortex (M1s) of subject 2 and 4 after surface based smoothing (a,c) and volumetric smoothing (b,d). Strong stripe-like activation clusters can be seen using surface-based filtering while volumetric filtering yields diffuse activation patterns.

References

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