Eliminating functional localizers using a probabilistic atlas of V1

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Introduction: Localizing fMRI-based activation estimates to a particular cortical area simplifies the analysis and interpretation of functional imaging data. Thus, functional localizers for visual cortical area boundaries are often performed as part of fMRI experiments probing visual function (1). However, commonly employed fMRI-based localizers, such as visual field mapping (2) or low-contrast moving stimuli, cost substantial scan time. In this work, we propose a method for predicting the boundary of the primary visual cortex (V1) from structural scans of an individual using a surface-based probabilistic atlas with the goal of eliminating the need for functional localizers. Using a custom-build 32-channel phased array head coil that enabled high-quality structural scans and high-SNR functional scans we were able to demonstrate good agreement between the V1 boundary predicted from structure alone and the boundary predicted using an fMRI-based visual field mapping technique. This validated method for V1 boundary prediction enables increased scan time devoted to fMRI by eliminating the need to map visual areas functionally.

Methods: Six neurologically normal human subjects were imaged using a TIM Trio 3T MRI system (Siemens, Erlangen, Germany) with a custom-built 32-channel phased array head coil (3). A three-dimensional T1-weighted structural scan was acquired using an MP-RAGE pulse sequence with voxel size of 1x1x1 mm, flip angle of 7°, TE=3.48 ms, TI=1100 ms, and TR=2530 ms. Functional BOLD measurements were achieved using a single-shot, gradient echo EPI sequence. The imaging parameters were TR=2000 ms, TE=30 ms, flip angle of 90°. Twenty-five 2 mm thick slices were acquired with 0.2 mm inter-slice gap and in-plane resolution of 2x2 mm. Sixteen functional scans of 64 measurements (128 s) each were performed while presenting standard phase-encoded visual stimuli (2,7) to map the representation of the visual field in cortical areas V1 and V2. A surface representation of the interface between gray and white matter was constructed from the structural volumes using the FREESURFER software package (4). The FSFAST software package was used to estimate the visual field representation for each functional voxel, which was projected onto the cortical surface for each subject. The fMRI-based V1 boundary location estimate was computed on the cortical surface using standard methods for locating reversals in the handedness of the coordinate system of the visual field representation in cortex. Surface-based intersubject registration (5) was performed to predict V1 location in individual subjects based solely on geometric properties of the cortical surface independent of any functional data. This atlas-based prediction of V1 location was derived from a surface-based probabilistic atlas of V1 generated from high-resolution, *ex vivo* structural MRI in human (6). After the V1 boundary was identified both structurally and functionally, the agreement between the boundaries was computed using a highly accurate method for measuring shortest-path distances along the cortical surface mesh in three dimensions (8). The agreement between the fMRI-based V1 boundary estimate and the probabilistic atlas-based prediction was evaluated by visual comparison and by computing the cortical surface-based distance between them.

Results: Data from a single subject are shown in Figure 1, indicating the fMRI-based V1 boundary estimate (red contours) and the probabilistic atlas-based estimate (blue contour) for both hemispheres illustrated on flattened patches of occipital cortex. The good agreement of the boundary estimates is representative of the subjects in the study. The right panel shows a histogram of the distance computed from the fMRI-based V1 boundary to the nearest vertex on the atlas-based V1 boundary over all subjects. The mean (±standard deviation) distance between the fMRI and atlas-based V1 boundary is 6.8 mm (±4.4 mm) for the left hemispheres and 6.7 mm (±4.6 mm) for the right hemispheres.

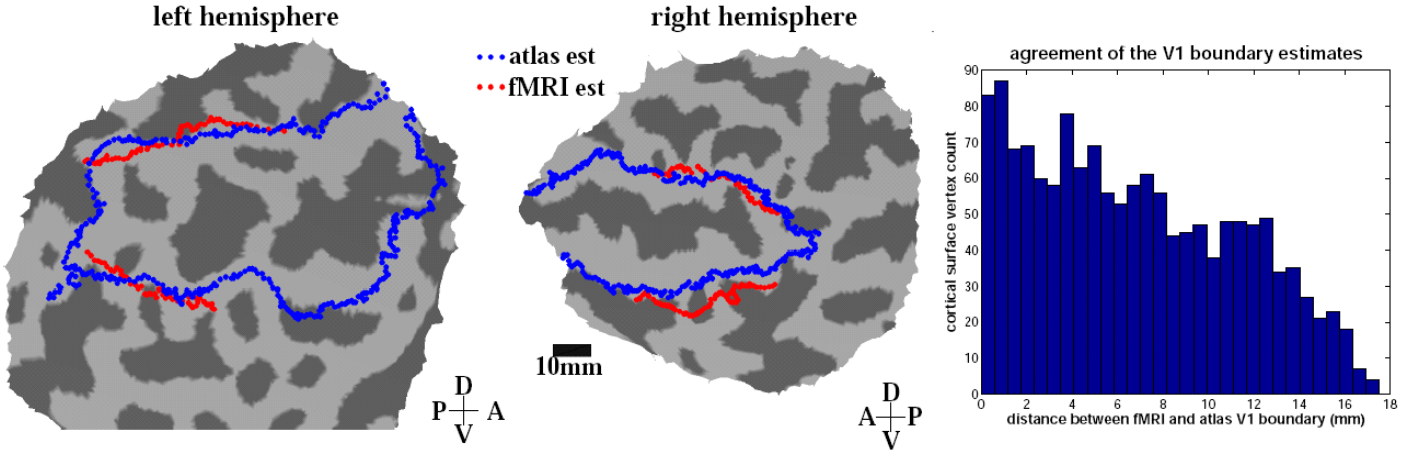

Figure 1: V1 boundary location is shown on flattened patches of each hemisphere of a single subject. Red and blue contours correspond to the location of V1 estimated via fMRI and predicted by the probabilistic atlas, respectively. The right panel shows the agreement of these independent estimates over all subjects.

Conclusion: These results suggest that the V1 boundary can be localized with an average error on the order of the size of two or three functional voxels based on purely structural information using a surface-based probabilistic atlas. Deriving visual area boundaries from standard structural scans allows increased scan time devoted to probing visual function by eliminating the need for functional localizers. Future work will concentrate on investigating whether the method presented here is effective for cortical areas other than V1.

References: 1) Saxe, R., et al. Neuroimage, 30 (4) 1088–96, 2006, 2) Sereno M.I., et al. Science, 268 (5212):889–93, 1995, 3) Wiggins, G.C., et al. Magn Reson Med, 56 (1):216–23, 2006, 4) Dale A.M., et al. Neuroimage, 9 (2):179–194, 1999, 5) Fischl B., et al. Hum Brain Mapp, 8 (4):272–284, 1999, 6) Hinds, O., et al. Neuroimage, In Press, 7) Polimeni J., et al. HBM Meeting, (128), 2005. 8) Balasubramanian, M., et al. Abstr Soc Neurosci, (923.11), 2005.

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