Surface-Based Analysis of Functional Magnetic Resonance Imaging Data

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Abstract. Surface-based visualization, atlases, and warping have demonstrated advantages for examining human and non-human brain morphology and the functional specialization of visual, auditory, somatosensory, and hippocampal anatomy. We describe the integration of surface-based techniques with functional imaging data, combining surface-based nonlinear registration algorithms with existing functional imaging software.

Van Essen and colleagues (1) discussed the advantages of surface-based visualization, atlases, and warping, for brain imaging studies. We recently reported surface-based analyses of brain morphology in healthy twins (2) and twins discordant for schizophrenia (3). Here we adapt these surface-based techniques to functional imaging data collected on the same twins, as outlined for a single subject below.

A standard magnetization prepared rapid gradient echo (MPRAGE, matrix: 256x256x128, resolution: .9766x.9766x1.2mm) 3D structural image was digitally filtered to reduce intensity inhomogeneity due to radio-frequency bias. Subsequently, the subject's MRI was aligned by 9-parameter transformation to an ICBM template and a 3D parametric surface model of the cerebral cortex was extracted from the subject's aligned MRI (4). A brain-only binary mask was created and manually edited to remove non-brain tissue, and gray (mostly neurons), white (mostly connections), and cerebrospinal fluid tissue classification was performed on the brain-only MRI. All these preprocessing steps were performed using the LONI Pipeline Processing Environment (5).

For the cortical surface models, a set of 15 sulci and 6 midline boundary lines were traced on each hemisphere's cortical surface model (6). These surface curves served as landmarks in the geometric averaging and warping of subjects, to remove inter-individual surface shape differences and to create group average models of the cerebral cortex on which statistical maps can be plotted (4).

BOLD sensitive echo-planar functional images (64x64x24, 4mm isotropic) were subjected to brain extraction, slice time correction, motion correction, and high-pass filtering using the Functional Software Library (FSL) (7), aligned to ICBM space, and masked with the gray matter mask. BOLD signal density was defined, similar to gray matter density in prior work (4), as the mean BOLD signal in the gray matter in a 15mm sphere centered at each point on the 3D parametric surface model. BOLD signal density values at each of the 65026 points on the cortex were then mapped to the subject's cortical surface models and written to a flat map (Figure 1a). The flat map EPIs were analyzed using FSL (7). Single subject p-maps were created using a voxel-wise corrected p-value of .05, and the results were displayed on the cortical surface of the individual subject (Figure 1).

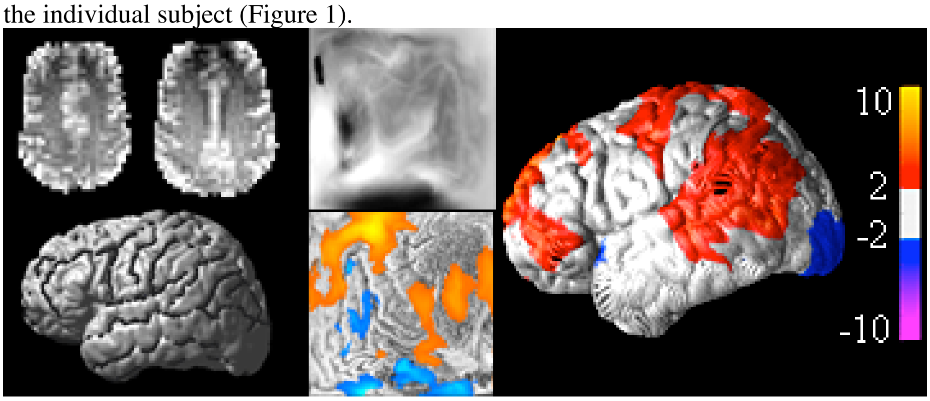

Figure 1: *Left top:* echo-planar imaging slices, left bottom: 3D surface model with sulcal lines, *middle top:* flat map of echo-planar image, *middle bottom and right:* flat map of thresholded t-statistic on flat anatomy and 3D cortical surface, respectively.

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