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High precision mapping of human visual cortex via fMRI

(NIBIB R01-EB1550 FY 02)

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The use of increasingly sophisticated neuro-imaging technologies requires correspondingly improved computational models and data analysis methods to avoid under-interpretation or mis-interpretation of the underlying neuroscience. One example is intrinsic optical recording, where historical over-estimates of spatial resolution of the instrumentation have led to qualitatively and quantitatively incorrect conclusions concerning a crucial aspect of cortical functional architecture: the pinwheel pattern of V1 [1]. Another major example is the use of fMRI to estimate the visuotopic structure of human striate and extra-striate cortex. Visuotopy provides the main validation and ground-truth for assessing the in-vivo spatial fidelity of fMRI, and is a fundamental measurement of human spatial vision. In the past, use of simplified one-dimensional models of cortical magnification factor, together with poorly controlled cortical surface reconstruction methods have led to widely divergent measurements in human and macaque. Here, we demonstrate the use of a full-field, two-dimensional quasiconformal model of the visuotopic structure of areas V1, V2 and V3 [2,3] to support a high precision measurement of human visuotopy. First, microelectrode and tissue section data from macaques is used to demonstrate the validity of the model, and to estimate its parameters. Then, fMRI data obtained from human brain and 3T and 7T is used to establish the corresponding map parameters in human [4]. The results of this study indicate that a significant fraction of occipital cortex may be viewed as a single "map-complex" whose conformal structure is shared by V1, V2, and V3, but whose anisotropy (topographic shear) varies from area to area. The importance of accurate surface reconstruction ("brain flattening") [6] is critical to this analysis. The parameters obtained from both human and macaque show remarkably small variation across individuals within and across the two species. This statement implies that the "shape" of V1 should also be the same in macaque and human. This was verified by MRI scanning of post-mortem human brain, at 7T, for up to 10 hours per sample, providing 200 micron isotropic resolution, in order to reconstruct the surface of the stria of Gennari [6]. In summary, this work provides an example in which the use of sophisticated computational modeling, improved brain flattening methods, and a series of small but significant experimental improvements have led to a deeper understanding of a major aspect of visual cortex.

Project (or PI) website

http://eslab.bu.edu

Publications

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4. Polimeni, J, et al Neuroimage 26(1):S128(2005).

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6. Hinds, O. et al Neuroimage 26(1): S140 (2005).