Defining Informative Voxels for detection of Cortical Structure in High-Resolution MRI

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Introduction

In vivo MRI at high field offers the exciting possibility for the detection of cortical structure, either by the direct imaging of cortical myelination and potentially by indirect detection of cytoarchitecture using contrasts such as diffusion anisotropy or magnetisation transfer. Recent papers have demonstrated the detection of cortical myelination patterns in the human visual cortex [1-4], and have shown correlation to functional activations [4, 5]. Whilst these results have illustrated the potential for detecting direct correspondence between cortical microstructure and functional activation, they do not provide any measure of the reliability and confidence of detection. By identifying the functional extent of human primary visual cortex (V1) using established fMRI techniques and identifying the proportion of this region where the stria of Gennari (known to co-localize) can be detected, we test the reliability of in vivo MRI to detect such myeloarchitectonic regions. We also introduce the concept of 'informative voxels', being those voxels in the image where we are confident that, should strong myeloarchitectonic features exist, they would be detected.

Methods

Five healthy volunteers were scanned on a 3 Tesla Varian Unity Inova MRI scanner. The location of the borders of V1 was determined using established fMRI paradigms (rotating checkerboard wedge stimulus, Fourier analysis of the data, grey matter segmentation and flattening [6-9]. To detect the myelinated layer of the striate cortex, magnetization prepared 3D FLASH images with an in plane resolution of 300 µm x 300 µm and a slice thickness of 1.5 mm were used [3, 10]. The scanning was performed over three sessions, each acquired at a different orientation: perpendicular to the calcarine sulcus (near coronal), parallel to the calcarine sulcus (near axial) and sagittal. Each data set was linearly registered to the standard resolution whole brain T1-weighted scan that was used as the basis of the cortical modelling above. Striate cortex was identified in the high resolution scans by three observers independently, and voxels where two of the three observers identified the stria of Gennari were transformed to the same flattened cortical space as the retinotopic mapping. From the cortical modelling process, maps of the angle of the cortex to the imaging plane were calculated and hence a measure of the effective resolution at each point of the flattened cortex determined. Similarly a measure of the curvature of the cortex at each point in the model was determined and also transformed to flattened space.

Results

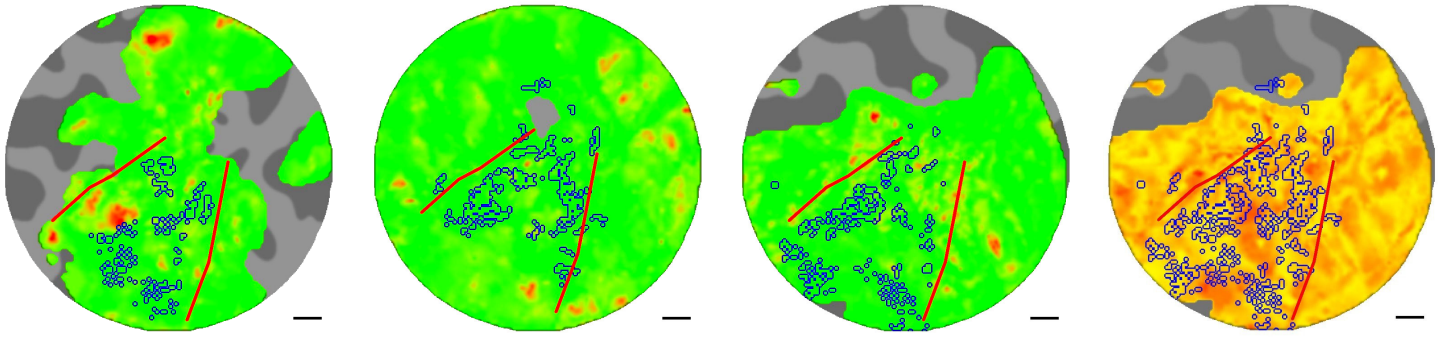

Figure 1. Colour from green (0.3 mm) to red (1.5 mm) represents effective resolution at each voxel in flattened cortical space. Red lines show the limit of V1 as determined by fMRI and blue lines represent the region where the stria of Gennari was detected in each view.

Figure 2. Colour from yellow to red represents the cortical curvature at each point. Blue lines show where the stria of Gennari was detected (all orientations combined).

Figure 1 shows the effective resolution (from green = 0.3 mm to red = 1.5 mm) of the high resolution structural scan at each point of the flattened cortex for each of the three imaging orientations on one subject. The region where striate cortex was identified is overlaid in blue and the boundaries of V1 as determined by the fMRI are shown as red lines. From these images it is clear that different orientations provide maximum sensitivity in different regions of V1. The regions of low sensitivity broadly correspond to regions where the effective resolution is lowest (red), although this does not fully account for regions where the stria of Gennari is not detected. However, from the cortical curvature shown in Figure 2 it is clear that low sensitivity also occurs when the curvature is high (red).

Discussion

The lack of the ability to detect the stria of Gennari across the whole of functionally defined V1 initially suggests that the potential for using such methods to detect myeloarchitecture patterns in other regions of the brain is limited. However, our data suggest that the reason for low sensitivity can be explained in terms of the effective resolution at any point of the convoluted cortex, and also by the curvature at any point. Thus, for any imaging orientation it should be possible to determine, with reference to the modelled cortex, the 'informative voxels' in that image. Thus it should be possible for any particular region of interest to determine an appropriate orientation in which to scan.

References

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