Reconstruction of the Optic Radiation by means of Combined DTI and fMRI

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Introduction

Basing on the information provided by Diffusion Tensor Imaging (DTI), fiber tracking (FT) algorithms allow the reconstruction of the pathways of the nerve bundles in the white matter (WM).

While DTI explores the structural organization of the white matter, the functional organization of the grey matter can be explored by means of functional magnetic resonance imaging (fMRI).

The aim of this work was to combine both methods, DTI and fMRI, to reconstruct the optic radiation connecting *lateral geniculate nucleus* (LGN) in thalamus with primary visual cortex (V1) in occipital lobe without any manual user interaction.

Methods

All measurements were performed on a 3 T MR-Scanner (Trio, Siemens, Germany). Five healthy subjects were studied. The V1 was located by mapping the cortical representation of visual polar angels. Fore that, a wedge was presented to the subject, rotating around a fixation point. Mapping angular representations allowed not only identification of V1 but also its separation in a ventral und dorsal part representing the lower and upper quadrants of the visual field (fig. 1a), respectively Blood-oxygen-level-dependent (BOLD) signal changes during stimulus presentation were measured by a gradient echo pulse sequence (TR 2000 ms; TE 34ms; flip angle, 90°). The voxel size was 2 × 2 × 2 mm^3; the 25 slices were perpendicular orientated to the calcarine sulcus.

The left and right lateral geniculate nuclei (LGN) were identified in an additional fMRI-run. Dartboard stimuli were presented in alternation to the left and right visual hemifield in blocks of 16 seconds. Left and right LGN stimulation was repeated 4 times. BOLD signal changes were measured by an echo pulse sequence (TR 2000 ms; TE 34ms; flip angle, 90°) with a voxel size of 3 × 3 × 3 mm^3.

The diffusion data were acquired with an isotropic spatial resolution of 1.4 mm^3 using double refocusing spin-echo sequence. This data sets, containing the visual cortex and LGN, were measured as 40 slices with the following parameters: TE = 94 ms, TR = 6000 ms, b-value: 800 s^2/mm, GRAPPA parallel imaging with an iPAT factor = 2. Data was composed of 16 averages measured in four acquisitions. Diffusion images were measured in 12 non-collinear and equally distributed directions. The fMRI and DTI data were processed using MATLAB (MathWorks, USA), SPM (UCL, UK), BrainVoyager (Brain Innovation, Maastricht, Netherlands) and in-house developed software for tractography and fiberselection.

The fibre-tracking algorithm was applied to all WM voxels [Fractional Anisotropy (FA) higher that 0.15]. Tracking was done using 27 equally distributed starting points inside each WM voxel. The resulting fibres were filtered out by using the information about ROI obtained in fMRI. Only fibres that ended or crossed both vicinities of LCN (3mm) and V1 (8mm) were taken for further analysis.

The resulting fibre bundle was segmented into two groups, depending on fibre distance to dorsal and ventral parts of V1.

Results

The described approach was able to reconstruct the optic radiation in 7 out of 10 acquired hemispheres. In 6 hemispheres separation of the resulting fibres into an upper bundle and lower bundle was possible. Figure 1b shows the reconstructed fibre bundles, the ROIs and the ventricles. Figures 1c and 1d show only LGN and V1 obtained from fMRI experiment and two reconstructed fibre bundles (red – inferior and green – superior).

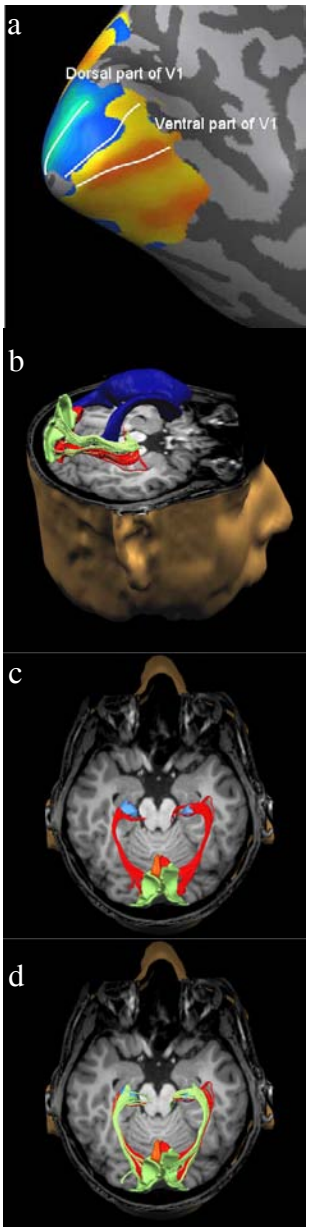

Figure1. a) Retiontopic organization of V1 with separated upper and lower quadrants. Colors correspond to phase of rotating wedge; b) Two reconstructed fiber bundles connecting CGL with V1. Ventricles are shown in blue;c) Inferior fiber bundle (red); d) Superior fiber bundle (green).

Discussion

Low FA values in relation to main fiber tracts in the brain and partial volume effects create uncertainty of diffusion direction estimation. This error in direction, made at the beginning of FT, will propagate along each fiber, therefore choosing WM close to ROI derived from fMRI is not the optimal solution.

Starting from all points in the white matter is a competitive solution and it provides the result free of mentioned errors.

Presented results relay completely on the MRI-measurements. No expert knowledge about the anatomy was used. The reconstructed tract suffers from the neighbourhood of another two, much larger and more anisotropic fibre tracts: the *inferior longitudinal fasciculus* and the splenium of the *corpus callosum*. Tensor model allows determination of only one direction of diffusion per voxel. In regions, where the mentioned tracts, combine or go near the optic radiation, the main direction of diffusion is calculated as the direction of the larger tract. The outer part of the Meyer's loop is also a problematic, because of fibres that turn back. The fibre-tracking algorithm is not allowed to turn back and in case of sharp curves and the presence of other fibre bundle, it may choose inappropriate direction. Nevertheless, it was possible to segment the optic radiation, according to its destination in the visual cortex.