

## Visualizing complex white matter anatomy in the live monkey at 3T using super-resolution track density imaging

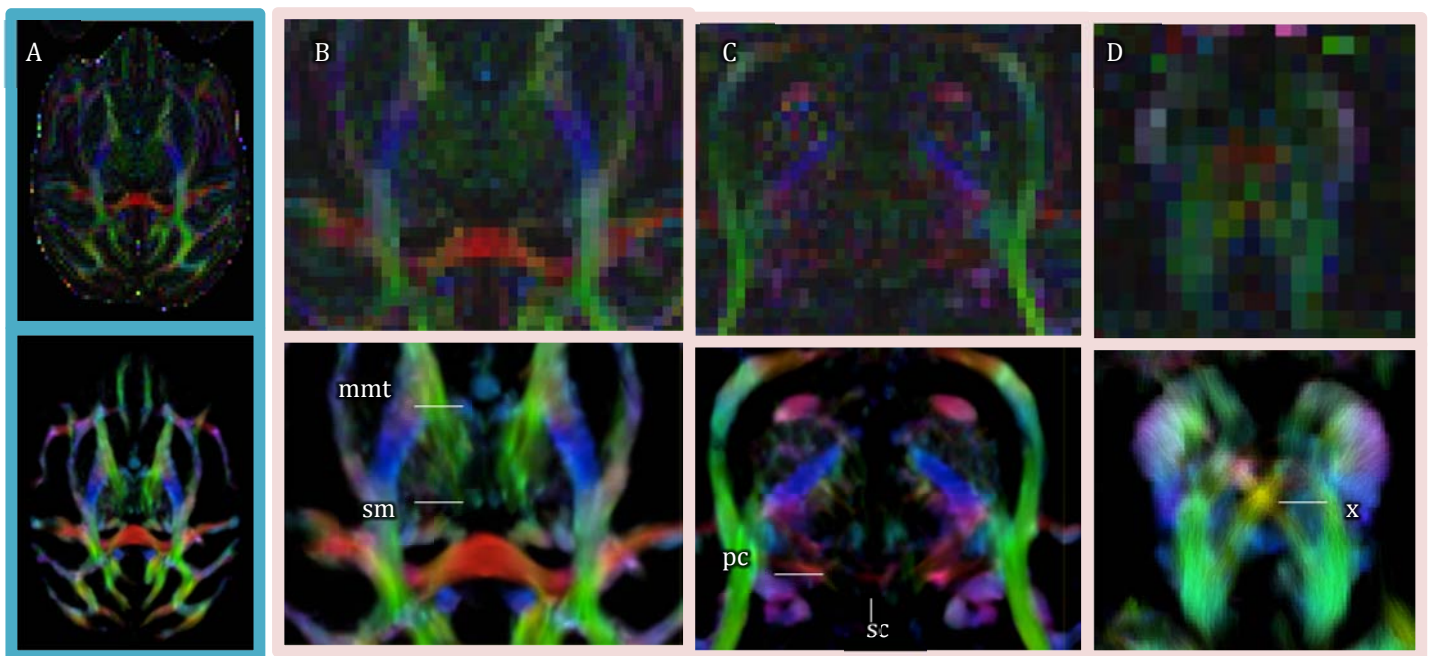
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**Background:** Recent high profile studies using diffusion MRI (dMRI) at high-field and using powerful gradient systems have demonstrated the potential of the technique for assessing brain connectivity<sup>1</sup>. However, such technology is not widely available and achieving high spatial resolution *in vivo*, is confounded by prohibitively long scan times. There is therefore a need to develop alternative techniques for investigating white matter *in vivo* at typically available field and gradient-strengths. This study uses short-tracts super-resolution track density imaging (stTDI)<sup>2,3</sup> data to demonstrate the feasibility of using 3T, 80mT/M, dMRI data for the *enhanced* visualization of complex white matter anatomy in the *living* monkey.

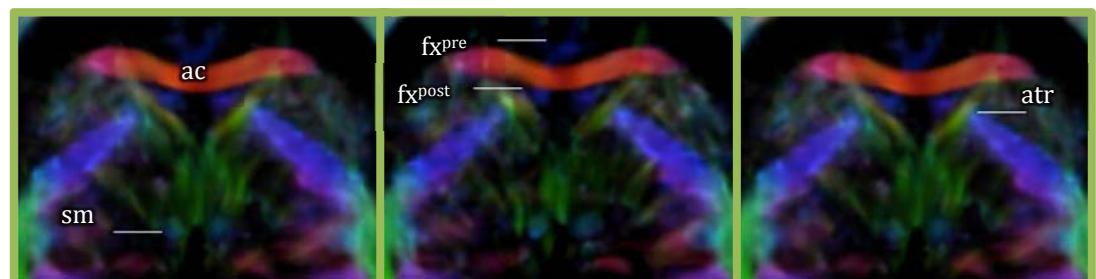
**Methods: Imaging:** DWIs were acquired (3T Siemens Trio) on a sedated adult macaque using an 8-channel head coil and 88mT/m customized gradient insert:  $b=2500$  s/mm<sup>2</sup>, 150 directions, 10 b0s, 1 mm isotropic voxels, repeated 8x with a total imaging time of approximately 2.5 hours. The 5 best quality datasets were then averaged to produce a single high SNR DWI dataset. **Tractography:** Probabilistic tractography was performed using constrained spherical deconvolution (CSD) in MRtrix<sup>4</sup>: initiation: FOD amplitude <0.25, step-size: 0.08mm, curvature threshold: 0.3. Termination: FOD amplitude <0.15 or outside brain mask. **TDI:** Derivative short tracks TDI and directionally-encoded TDI (DEC-stTDI) maps were created using in-house software integrated with MRtrix: Track length >5 - <10mm, 80,000,000 tracks, grid size 0.25mm<sup>3</sup>. In the DEC stTDI maps the maximum track length was constrained to preserve medium-range information whilst reducing the dominant contribution of long-range fibre bundles to voxel-intensity. **Reliability:** As only a single-subject was used, a residual bootstrapping approach was to generate 100 realisations of the same dataset in order to compare regional intensity variations attributable to noise<sup>5</sup>.

**Results:** Figures 1 illustrates the enhanced anatomical contrast of key structures in the diencephalon and brain stem, barely visible at the acquisition resolution. Fig 2 illustrates the variation in intensity due to noise in an axial slice at the level of the anterior commissure, and highlights the reproducibility of key structures only clearly identifiable in the super-resolution maps.



**Fig 1:** Comparison of original, 1 mm resolution axial colour FA maps (top row) and stTDI, 0.25 mm colour maps (bottom row) for selected slices: (A) whole brain mid-axial slice through the thalamus. (B) zoomed in slice (A) illustrating mammillothalamic tract (mtt), and stria medullaris (sm). (C) central view of thalamus at level of the posterior commissure (pc), illustrating the sc: superior colliculi. (D) brain stem illustrating the decussation of the superior cerebellar peduncles: x

**Fig 2:** Intensity variation in stTDI maps for 3 different noise realisations: original (left) and in 2 random images selected from 100 bootstraps (middle & right). Note the preservation of major structures bilaterally: anterior commissure (ac), pre- and post commissural fornix ( $fx^{pre}$ / $fx^{post}$ ), anterior thalamic radiation (atr) and variation in central thalamic region (green).



**Discussion & conclusion:** We have demonstrated that stTDI can be used to generate biologically meaningful super-resolution anatomical contrast in the live monkey using a 3T system and 88mT/m gradient insert. The bootstrapping results add confidence to the observed anatomical contrast. The stTDI approach remains susceptible to diffusion modelling limitations, noise and partial volume effects; however, it may contribute valuable complementary *qualitative in vivo* structural information when combined with other imaging modalities.

**References:** 1. Wedeen et al, *Science*, 2012 2. Calamante et al, *NeuroImage*, 2010 3. Calamante et al, *NeuroImage* 2011, 4. Tournier et al, *International Journal of Imaging Systems and Technology*, 2012. 5. Dhollander et al, *ISMRM* 2012