Microscopic Diffusion Anisotropy Imaging

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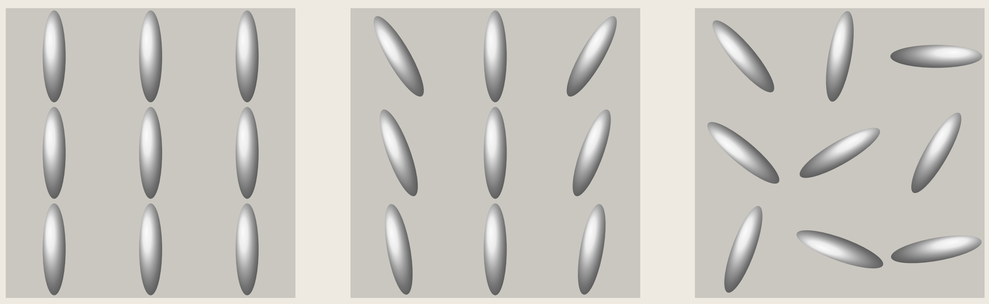
Purpose

- The objective is to disentangle the microscopic diffusion process from fibre crossings and orientation dispersion.
- We have pioneered an easy way of microscopic diffusion mapping based on off-the-shelf sequences achievable in clinical settings.

Macroscopic vs microscopic anisotropy



For any fixed gradient timing and gradient magnitude (thus fixed *b*-value):

- The spherical mean of the diffusion signal over the gradient directions does not depend on the orientation distribution (Kaden *et al.*, MRM, 2016).

Spherical Mean Technique (SMT)

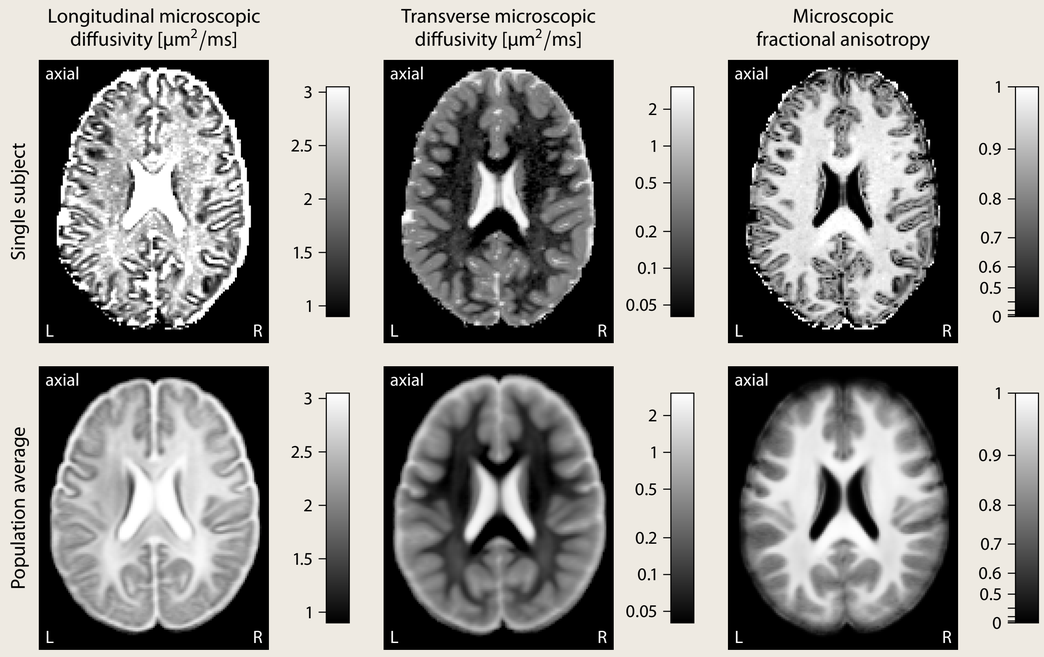
Simple, fast and robust estimator of microscopic diffusion anisotropy without knowledge of the neurite orientation distribution (Kaden *et al.*, MRM, 2016):

- *Step 1*—Formulate a microscopic diffusion signal model for a single micro-domain, *e.g.* microscopic diffusion tensor or multi-compartment model.
- *Step 2*—(a) Acquire two or more *b*-shells with uniformly distributed gradient directions. (b) Compute the mean diffusion signal for each *b*-shell separately.
- *Step 3*—Fit the spherical mean version of the microscopic diffusion model to the measured mean signals.

Diffusion data

- Human data: 500 Subjects Data Release, Human Connectome Project, WU-Minn Consortium; 90 gradient directions for each *b*-shell of 1000, 2000 and 3000 s/mm^2 (Van Essen *et al.*, NeuroImage, 2012).
- Mouse data: Conditional knockout model of Tuberous Sclerosis Complex; 30 gradient directions for each *b*-shell of 3000 and 6000 s/mm^2 (Kelm *et al.*, NeuroImage, 2016).

Microscopic diffusion anisotropy (Kaden *et al.*, MRM, 2016)

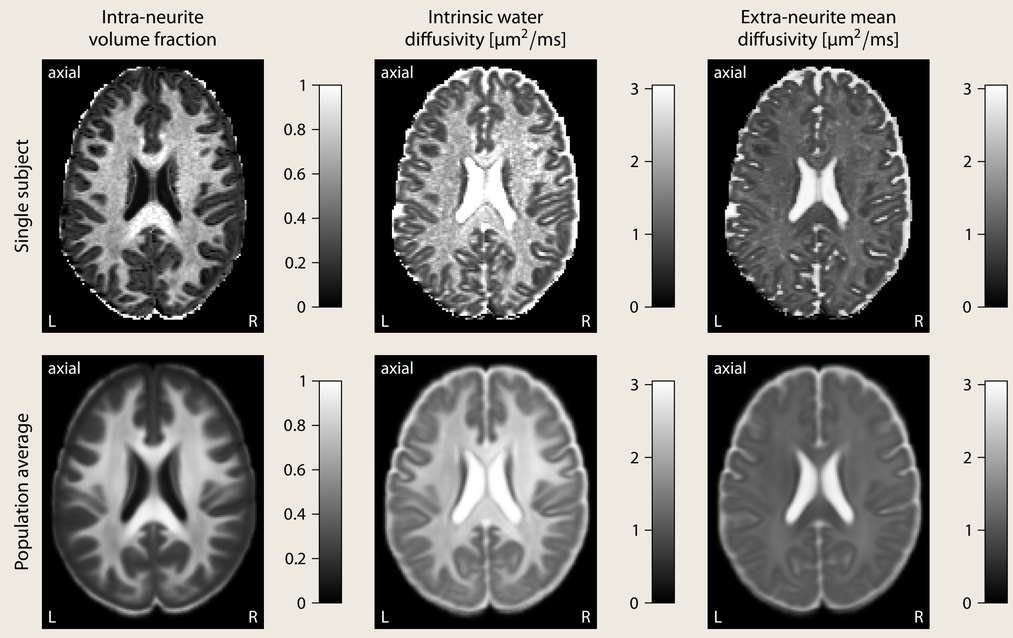


- Quantitative mapping of the microscopic or per-axon diffusion coefficients, unconfounded by fibre crossings and orientation dispersion.

References & Software

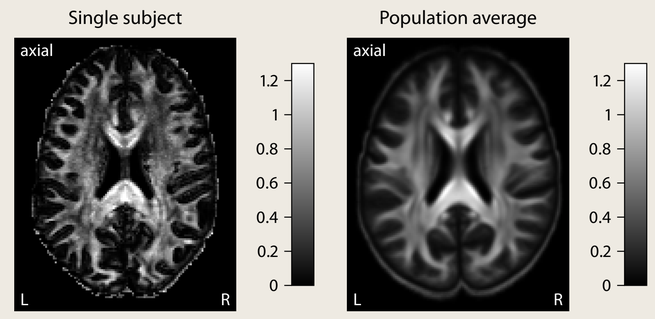
- Kaden E., Kruggel F., Alexander D.C., Quantitative mapping of the per-axon diffusion coefficients in brain white matter, MRM, 75:1752–1763, 2016.
- Kaden E., Kelm N.D., Carson R.P., Does M.D., Alexander D.C., Multi-compartment microscopic diffusion imaging, NeuroImage, 2016.
- The software is available online at *https://ekaden.github.io*.

Multi-compartment microscopic model (Kaden *et al.*, NeuroImage, 2016)



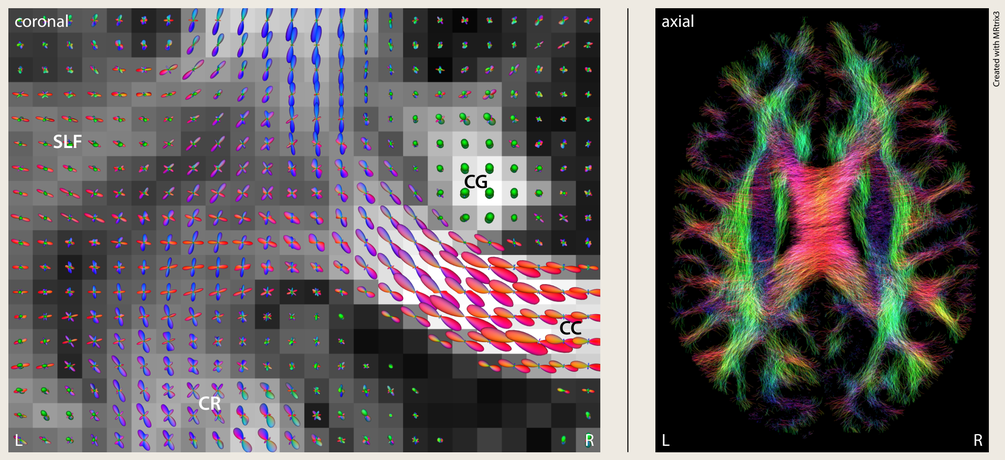
- SMT does not assume fixed diffusivities. Indeed, the intrinsic diffusivity, if estimated from the data, varies substantially over the brain.

Orientation dispersion entropy



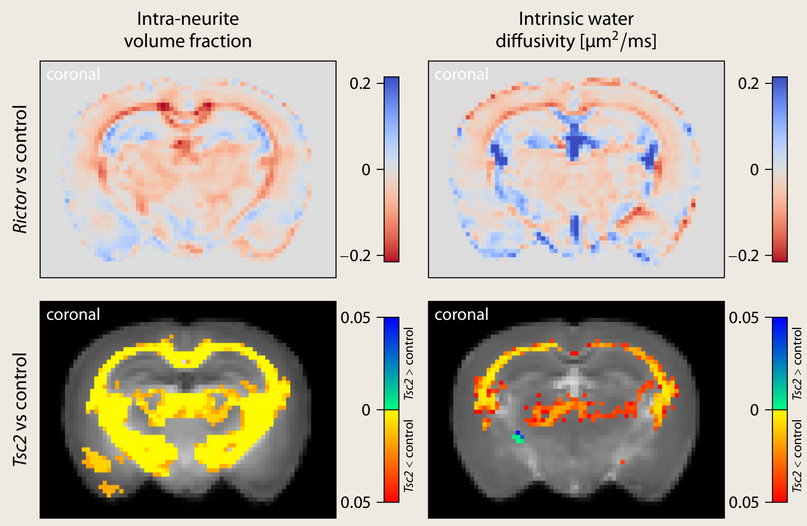
- This summary statistics of directional heterogeneity takes fibre crossings and orientation dispersion into account.

Connectivity mapping



- Spherical deconvolution with spatially varying response function to recover the fibre orientation distribution (Kaden *et al.*, NeuroImage, 2008).

An *ex-vivo* hypomyelination mouse study



- SMT provides direct sensitivity to microstructural abnormalities in tissue with complex directional structure.

Acknowledgements

This work was supported by grants EPSRC EP/G007748/1, EPSRC EP/M020533/1, EPSRC EP/N018702/1, H2020 634541-2, NIH R01 EB001744, NIH 5K08 NS050484, NIH T32 EB014841 and NIH S10 RR029523. Data were provided in part by the Human Connectome Project, WU-Minn Consortium (Principal Investigators: David Van Essen and Kamil Ugurbil; 1U54MH091657) funded by the 16 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience Research; and by the McDonnell Center for Systems Neuroscience at Washington University.

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