Beyond 256 shades of grey: Quantitative MRI for probing brain microstructure

Quantitative MRI (qMRI) finds increasing application in neuroscience and clinical research due to its greater specificity and its sensitivity to microstructural properties of brain tissue. Multi-parameter mapping (MPM) is a comprehensive qMRI protocol [1], including an acquisition, modeling, and processing framework that ultimately provides high-resolution whole brain maps of the magnetization transfer saturation ($\mathrm{MT_{sat}}$), proton density (PD), longitudinal and effective transverse relaxation rate ($R_1 = 1/T_1$ and $R_2^* = 1/T_2^*$).

The qMRI signal has a physical interpretation, linked to the brain tissue microstructure properties such as macromolecular, iron, and water content, for both grey and white matter (GM/WM) tissues. Morphometric analysis (e.g. "voxel-based morphometry" of GM volume or cortical thickness) are still possible but "voxel-based quantification" (VBQ) analysis can complement these and provide new insights. Nevertheless the quantitative nature of the images and their improved contrast, especially in subcortical areas, calls for specific processing steps, as compared to standard structural MRI, at the individual and group level.

For a VBQ approach, one must take into account issues related to tissue segmentation and spatial normalization, for which updated "tissue probability maps" should be employed [4]. Smoothing should also be applied separately for grey and white matter, in order to avoid mixing tissue properties at the interfaces and introducing partial volume effect. The "hMRI toolbox" [2] and qMRIlab [3] are easy-to-use open-source tools for creating and processing these qMRI data.

Reference:

[1] Weiskopf et al. (2013), Quantitative multi-parameter mapping of R1, PD*, MT and R2* at 3T: a multi-center validation. Frontiers in Neuroscience, 95. https://dx.doi.org/10.3389%2Ffnins.2013.00095

[2] Tabelow et al. (2019), hMRI – A toolbox for quantitative MRI in neuroscience and clinical research. NeuroImage 2019 July; 194(1):191–210. https://doi.org/10.1016/j.neuroimage.2019.01.029 & http://hdl.handle.net/2268/232311

[3] Cabana et al. (2016), Quantitative magnetization transfer imaging *made* easy with *q*MTL*ab*: Software for data simulation, analysis, and visualization. Concepts in Magnetic Resonance Part A, 44A(5) 263–277

[4] Lorio et al. (2016), New tissue priors for improved automated classification of subcortical brain structures on MRI. NeuroImage, 130:157-166. https://doi.org/10.1016/j.neuroimage.2016.01.062