Enhanced Mylein-related contrast across the human brain at 7T using the ratio of high resolution T1 and T2* weighted images.

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INTRODUCTION.
In vivo MR anatomical contrast offers considerable promise for mapping cortical areas, in individuals and in populations, and for enhancing the interpretability of functional maps. Myelo-architectural features have been visualized using MRI in humans, including the stria of Gennari in V1 [1] and tripartite lamination of area 4 [2]. Comparing T_1 and T_1 w (weighted) intensities to histologically measured myelin reveals strong correlations and has enabled accurate delineation of several cortical areas [3]. MR contrast in T_2* w images is influenced (among other contributions) by iron. Myelin and iron are strongly co-localized within cortical gray matter [4]. Recently [5] T_1w and T_2w images acquired at 3T were successfully combined (as a ratio) to enhance myelin related anatomical contrast in vivo. At ultra-high fields (7 Tesla and above), in addition to increases in functional contrast, anatomical contrast is also enhanced [6], and higher SNR permits higher spatial resolution images. However, much more so than at 3T, residual bias fields due to transmit and receive profiles contaminate the images and reduce the ability to disambiguate subtle regional variations in the gray matter signal. Further, obtaining T_2 weighted images at 7T over large parts of the brain can be difficult due to both the transmit profile and SAR limitations. We have previously shown that (GE-based) proton density images can be used to flatten a T_1 w (GE-based) MPRAGE image, resulting in more uniform gray/white contrast [7]. Here, we build on this idea of using ratio images to reduce intensity biases from the RF coil profile, while altering the inherent T_2* weighting between the images with the objective of improving the visualization of intra-cortical myelo-architectural features in vivo (as done previously at 3T [5]) by taking advantage of the higher resolution and inherent contrast available at 7T. We provide evidence that mapping the ratio between T_1 and T_2* weighted images at 7T can reveal heavier myelination of several cortical areas in single subjects.

MATERIAL AND METHODS. Measurements were performed at 7T (Siemens, Erlangen, Germany) using a 24 channel receive volume coil (Nova Medical). Three healthy volunteers (3 males) without prior history of psychiatric or neurological illness gave their informed consent and participated in the study. The scanning protocol comprised two T_1 weighted (3D-MPRAGE; 0.6 mm isotropic TR = 3100 ms; TI = 1500 ms), T_2* weighted (0.6 mm isotropic, TE = 16 ms) and Proton Density (0.6 mm isotropic, TE=4 ms) weighted images (total scanning time ~ 40 min per subject). PD and T_2* images were acquired using the identical 3D acquisition train (MPRAGE), however, without the adiabatic inversion that is used for the T_1 weighted acquisition. The complex average of the two T_1w images was used for further analysis in individual subjects. All anatomical images were complex re-sampled at a resolution of 0.3 mm isotropic to improve visualization (see figure 1 for two transversal slices as acquired in one subject). T_1w and PDw images were used to obtain T_1w/PDw anatomical images, largely unbiased by the RF coil profile [6], with the adiabatic inversion providing relatively uniform T_1 contrast. The ratio between T_1w and T_2*w (T_1w/T_2*w) images was also used to partially remove coil related inhomogeneities, while in turn enhancing intra-cortical contrast related to iron and myelin. Residual low spatial frequency intensity biases on both the T_1w/PDw and the T_1w/T_2*w images were removed using the inhomogeneity correction as implemented in BrainVoyager (BrainInnovation, Maastricht, The Netherlands). All sub-sequent analyses were performed on images resampled to 0.5 mm isotropic. Unbiased T_1w/PDw were (automatically) segmented to delineate the white/gray matter and gray matter/ cerebrospinal fluid boundaries. Small imperfections in the automatic procedure were manually corrected. Surfaces representing the white/gray matter boundary were obtained for each individual subject and hemisphere. The anatomical contrast in the T_1w/T_2* images was mapped exclusively in the cortical gray matter ribbon as obtained from the segmentation procedure.

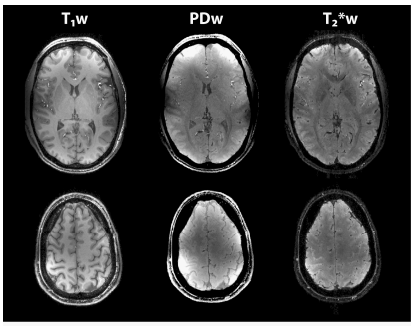

Figure 1

RESULTS. Figure 2 shows the unbiased T_1w/PDw image and the ratio of T_1w and T_2*w images (after inhomogeneity correction) together with the result of the segmentation of the unbiased T_1w/PDw data (binary image with gray and white matter voxels colored accordingly). The ratio of T_1w and T_2* w images shows enhanced anatomical contrast in both the white matter and gray matter (e.g. note the brighter signal in the motor cortex in the higher transversal slice [*add arrow?]*). Figure 3 shows a thresholded (20% most myelinated voxels) map of heavily myelinated cortex overlaid on the T_1w images together with a lateral view of the map as projected on the surface reconstruction of the left hemisphere (single subject results). Higher intracortical T_1w/T_2* signal intensity is clearly mapped in the motor cortex as well as early auditory areas and visual areas, including MT+, which are known to have higher myelin content [5].

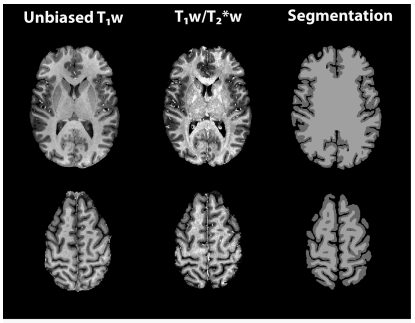

Figure 2

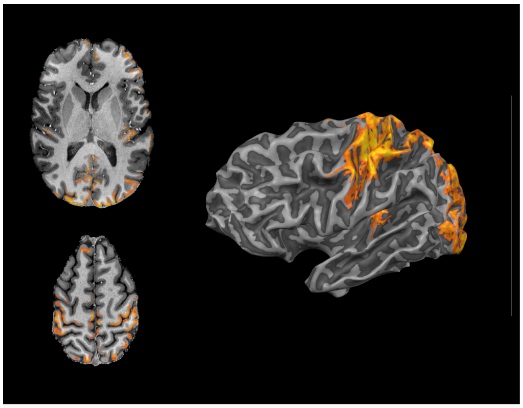
Figure 3

DISCUSSION. Our results show that T_1w and T_2*w data can be successfully combined to obtain a similar source of contrast at 7T as was previously obtained by the combination of T_1w and T_2w data at 3T [5]. Further, using the increased contrast and signal to noise available at ultra-high fields [8] and accurate image processing (inhomogeneity correction and segmentation), we demonstrate anatomical features correlated with myelin content can be mapped in individual subjects at very high resolution (0.6 mm isotropic), making possible a more detailed layer dependent analysis.

ACKNOWLEDGMENTS. Work supported in part by the National Institutes of Health (R01 EB000331, P30 NS057091, P41 RR08079), Human Connectome Project (1U54MH091657-01). The 7 T magnet purchase was funded in part by the WM KECK Foundation.

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