STRUCTURAL CONTRAST ENHANCEMENTS BY NOVEL WAY TO COMBINE T1- AND T2-WEIGHTED MR IMAGES

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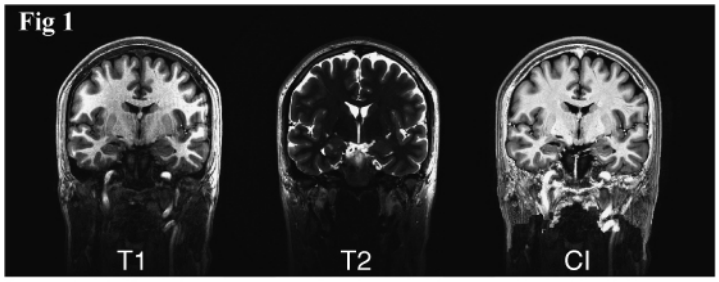
Target audience: Researchers and clinicians utilizing brain structural MR images for morphometric and volume analysis, and for clinical purposes.

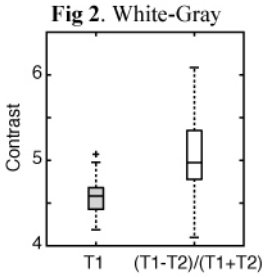
Purpose: The application of MRI-based methods for comparing cerebral volumes, such as voxel-based morphometry and regional segmentation, has proven highly informative in studies of neuropsychiatric disorders. However, the accuracy and sensitivity of such approaches is critically dependent upon the acquisition of high-quality structural MR images, especially with respect to signal homogeneity and tissue contrast resolution. In this study, we propose a new structural image contrast that is based upon a novel combination of T1- and T2-weighted images. A specific combination of T1 and T2 images holds the potential to reduce noise and enhance contrast resolution between brain structures. While a similar method of combining T1 and T2 images has been proposed by Glasser and Van Essen[1], their technique targeted comparisons of the myelin content across regions. Our approach, in contrast, aims at enhancing tissue contrast between gray and white matter and between subcortical nuclei that differ in white matter content for better structural analysis. We evaluated the utility of the new contrast image using automatic segmentation software.

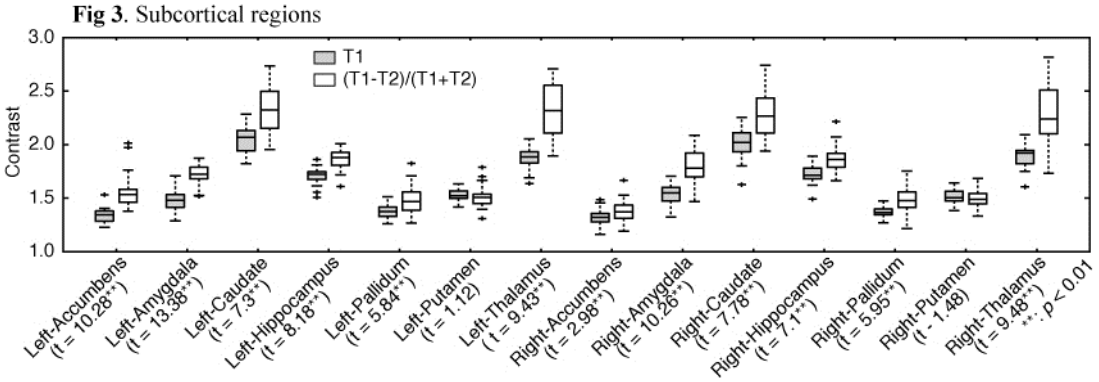
Methods: Participants; 30 healthy subjects (age 22–54 years, 18 female) participated in IRB-approved study. MRI: Imaging was conducted on a General Electric Discovery MR750 whole-body 3 Tesla MRI scanner with 32ch Nova Medical brain array. T1-weighted images were obtained with an MPRAGE sequence (SENSE acceleration=2, TR/TE=9/3.4ms, FA=8°, TI=725ms, FOV/slice=240/2mm, matrix=512×512, 80 coronal slices). T2-weighted images were obtained with Fast Spin Echo PROPELLER sequence with TR/TE=10s/135ms and the same spatial resolution as T1-weighted image. Since these images did not cover the whole brain, standard resolution (1mm isotropic) T1-weighted images covering whole brain were also obtained. This lower-resolution T1-weighted image was used for warping individual brain to the atlas template, which was necessary for automatic segmentation process. Image fusion: After the T2 image was aligned to the T1 image, the two images were combined by the equation, CI=(T1-T2)/(T1+T2) to form the combined image (CI). This CI combination can enhance image contrast because the bias field common to T1 and T2 can be cancelled and T1 and T2 images have opposite intensities. Fig. 1 shows example coronal slices of T1, T2, and CI. Evaluation of segmentation contrast: To examine the utility of the CI, we assessed differences in the performance of an automatic segmentation algorithm on the basis of the improved contrast resolution of the combined image. We used FAST in FSL[2] to segment gray and white matter regions. A probabilistic atlas was used to initialize the segmentation. We also evaluated the contrast between subcortical regions segmented by FreeSurfer 5.1[3]. The segmentations were performed for T1 and the CI independently. To evaluate the contrast of the T1 image a bias-field-corrected image was used.



Results: Fig. 2 shows a bar plot of contrast between white and gray matter structures as segmented by FAST for all subjects. The contrast was evaluated with a Fisher score (squared difference of mean intensities divided by sum of variances). The CI had significantly higher tissue contrast than the T1 image ($t = 4.85$, $p < 0.01$). Fig 3 shows the contrast of subcortical regions segmented by FreeSurfer. Contrast was evaluated only at voxels on the border of each region. The combined image had significantly higher contrast than the T1 image in all regions excepting the putamen. The volume estimations also differed significantly between the T1 and the CI images, indicating that the CI contrast enhancement affects the cerebral volumes obtained by FreeSurfer.

Discussion: We introduce a novel approach for combining T1 and T2 MR images to enhance the contrast between white and gray matter and between subcortical nuclei that differ from adjacent grey matter structures with respect to their content of white matter plexuses. The CI=(T1-T2)/(T1+T2) significantly enhanced contrast between white and gray matters and between subcortical structures. The contrast enhancement offered by CI also may improve segmentation accuracy when using automatic segmentation software, resulting in more accurate neuromorphometric analyses of the human brain.





References: 1) Glasser MF, Van Essen DC. Mapping human cortical areas in vivo based on myelin content as revealed by T1- and T2-weighted MRI. *J Neurosci.* 2011;31(32):11597-11616.; 2) http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FAST; 3) http://surfer.nmr.mgh.harvard.edu