Cortical thickness measurements with MPRAGE and MP2RAGE at 3T

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Introduction: Cortical thickness (CTE) is a widely used tool to study neurodegenerative disorders and partial volume (PV) estimation has been shown to improve this measure [1]. The recent MP2RAGE sequence [2] is a promising candidate acquisition over standard sequences such as MPRAGE because of properties such as bias-free images and high gray-white matter contrast, thereby reducing pre-processing for automated morphometric image processing methods. However, cortical surfaces reconstructed with MP2RAGE have been reported to be thinner than those reconstructed with MPRAGE [3]. In addition, the reproducibility was reported to be slightly lower [3]. Recent work [4] suggested that PV modelling in MP2RAGE must be carefully chosen because the MP2RAGE bias-free image is obtained from a quadratic combination of two images, which modifies the assumption that the signal in a PV voxel is a linear combination of two pure tissue signals. We compared PV estimation used for cortical thickness measurement between MPRAGE and MP2RAGE with respect to bias and precision and reproducibility.

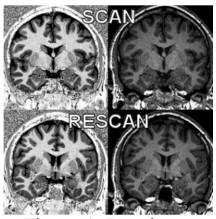

Figure 1. Imaging protocol with both MP2RAGE (left) and MPRAGE (right).

Data: Five healthy volunteers were scanned with a 3T Siemens Skyra Scanner with a 20-channel head coil. They underwent scan-rescan 3D isotropic (1mm^3) MP2RAGE (TI1/TI2/TE/TR/flip1/flip2/BW= 700ms/2500ms/2.98ms/5000ms/4°/5°/240Hz/px) and MPRAGE (TI/TE/TR/flip/BW) = (900ms, 2.07ms, 2300, 230Hz/px) protocols. The subjects were asked to stand up between each pair of acquisitions (one pair = MPRAGE + MP2RAGE) and had thus different positions in the scanner between the scans (Fig 1).

Methods: Each of the four scans for all the subjects were segmented into three pure tissue classes (gray matter (GM), white matter and cerebrospinal fluid) using an established method [5].Cortical thickness was calculated from GM PV maps: 1) MP2RAGE, GM PV maps were computed using two different PV models as proposed in [4] (LIMe: linear, BiExp: bi-exponential); 2) MPRAGE, GM PV maps were computed using the linear PV model (LIMe), and considered as the reference for this study. Hence, for each subject, three cortical thickness maps (2 for MP2RAGE and 1 for MPRAGE) were obtained for both the scan and for the rescan. These six maps were aligned to a common template mesh to compare cortical thickness values on a vertex-wise basis. Vertex-wise signed CTE difference were computed and reported on brain surface (Fig 2). The average CTE for the whole neocortex was also computed and compared between methods using the non-parametric Wilcoxon signed rank test. Reproducibility was estimated by calculating the determination coefficient between average cortical thickness by hemisphere between the scan and rescan.

Results: No significant difference in CTE in average over the neocortex was found using LIMe on MPRAGE and BiExp on MP2RAGE, however LIMe MP2RAGE resulted in significantly ($p<0.01$) lower CTE (2.90 mm) compared to BiExp MP2RAGE (2.98 mm), consistent with differences reported elsewhere [3]. Locally, the magnitude of difference between scan and rescan were smaller using MP2RAGE than with MPRAGE. Between scan and rescan reproducibility was found to be in descending order: BiExp MP2RAGE (R^2=0.98), LIMe MP2RAGE (R^2=0.98), and LIMe MPRAGE (R^2=0.79) (Fig. 3).

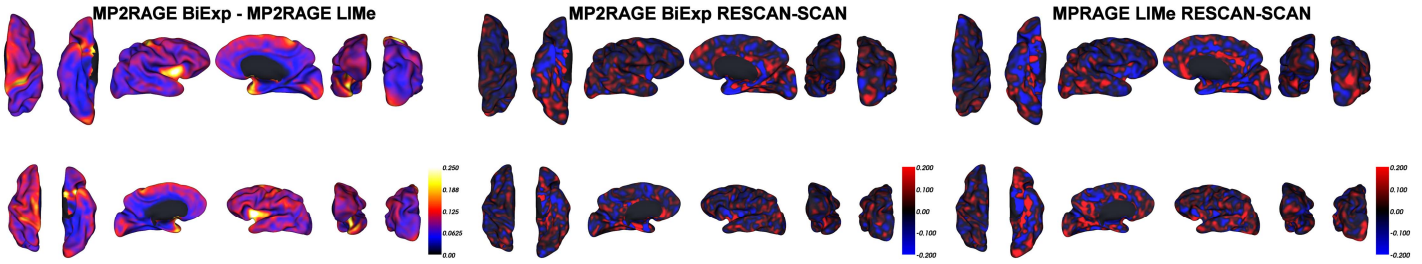

Figure 2. Cortical thickness differences mapped on a brain surface template between two PV models for MP2RAGE (left). Cortical thickness reproducibility maps of MP2RAGE BiExp (center) and MPRAGE LIMe (right). Scale bars in mm.

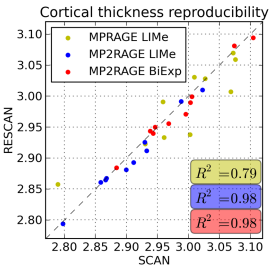

Figure 3. Average cortical thickness per hemisphere.

Conclusion: Cortical thickness bias between MPRAGE and MP2RAGE could be explained and corrected by a new bi-exponential PV model. MP2RAGE was also found to be more reproducible than MPRAGE when computing cortical thickness and should therefore be considered for measuring cortical thickness in clinical studies.

References: [1] D. W. Shattuck *et al,.* "Magnetic Resonance Image Tissue Classification Using a Partial Volume Model," *NeuroImage*, vol. M, pp. 856–876, 2001.[2] J. P. Marques *et al.,* "MP2RAGE, a self bias-field corrected sequence for improved segmentation and T1-mapping at high field," *Neuroimage*, vol. 49, no. 2, pp. 1271–1281, 2010. [3] K. Fujimoto *et al.,* "Quantitative comparison of cortical surface reconstructions from MP2RAGE and multi-echo MPRAGE data at 3 and 7T," *NeuroImage*, 2013. [4] Q. Duché *et al.,* "New Partial Volume Estimation Methods for MRI MP2RAGE," in *MICCAI 2014*, Springer, 2014, pp. 129–136. [5] O. Acosta *et al.,* "Automated voxel-based 3D cortical thickness measurement in a combined Lagrangian-Eulerian PDE approach using partial volume maps.," *Med. Image Anal.*, vol. 13, no. 5, pp. 730–743, Oct. 2009.