Validation of Cortical Thickness/Volume Data from Multi-Echo MPRAGE Scans with Variable Acceleration in Young and Elderly Populations

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Target Audience: Researcher groups conducting volumetric brain morphometry, with concerns over optimal pulse sequence or hardware.

Purpose: Automated MRI-derived measurements of in-vivo human brain volumes from anatomical scans can provide novel insights into normal and abnormal neuroanatomy, but only a few studies have probed the repeatability and effects of sequence-dependent parameters on these measurements.[1] The multi-echo MPRAGE (MEMPRAGE) sequence was implemented to reduce signal distortion by using a higher bandwidth and averaging multiple echoes to recover SNR while using variable T_2* decays to enhance contrast, and hence, cortical segmentation.[2] To ensure maximal efficiency, a rapid 2-minute MEMPRAGE protocol has been implemented for anatomical scans. This yields quantitatively repeatable morphometric information on sub-cortical/white-matter structures across different scanners and days,[3] and in comparison to scans employing a higher-resolution MEMPRAGE protocol with lower image acceleration.[4] Here, we report the morphometric results for the cortex obtained from the two MEMPRAGE scans, acquired in the same session, and contrast results using the two different vendor-supplied head-coils, and across populations.

Methods: All measurements were performed using a 3.0 T MRI scanner (MAGNETOM Trio, A Tim System, Siemens Healthcare, Erlangen, Germany). 45 subjects (mean age 22.7 years, 26 male) were scanned using the 32-channel head coil, 31 subjects (mean age 21.8 years, 19 female) were scanned using the 12-channel head coil. Additionally, 17 elderly subjects (mean age 72.6 years, 9 male) were scanned using the 32-channel head coil. All gave written informed consent according to a protocol approved by the local IRB. Each session included a high-resolution MEMPRAGE scan acquired in 6 min 44 sec (TE = 1.64, 3.50, 5.36 and 7.22ms, TR = 2530 ms, TI = 1200 ms, FOV = 256 × 256 mm, 176 slices, voxel size = 1.0 mm^3, parallel imaging (PI) acceleration = 2 (p2), bandwidth = 651 Hz/px); and a rapid MEMPRAGE scan acquired in 2 min 12 sec (TE = 1.54, 3.36, 5.18 and 7.01ms, TR = 2200 ms, TI = 1100 ms, FOV = 230 × 230 mm, 144 slices, voxel size = 1.2 mm^3, PI = 4 (p4), bandwidth = 651 Hz/px). The anatomical scans were analyzed using the FreeSurfer toolkit,[5] after the two scans from each subject were aligned using the FreeSurfer robust registration tool.[6] An automated parcellation of the cortex, subcortical and white matter structures was performed, and the estimated Total Intracranial Volume (eTIV) was calculated. To aid analysis, the 33 cortical regions of the Desikan-Killiany atlas were combined into five principal cortical lobes.[7] Correlation and Bland-Altman difference plots were made for the thickness and volume of each cortical lobe determined from each scan.

Results: Correlation for the gray matter volume for each of the 5 aggregated cortical lobes was high. R^2 for all three population groups = 0.93-0.97 (12 ch), 0.93-0.99 (32ch young adult); 0.81-0.95 (32ch elderly). Correlation was lower for cortical thickness: 0.64-0.79 (12 ch), 0.66-0.91 (32ch young adult); 0.64-0.84 (32ch elderly). Example Bland-Altman plots are shown in Fig. 1. Analysis showed a small but sometimes significant bias in both cortical thickness and gray matter volume, 1.9-6.7% and 5.8-9.5% (12ch); -0.3-5.8% and 3.7-7.7% (32ch young adult); 0.6-8.4% and 4.8-10.5% (32ch elderly) respectively. Bland-Altman slopes were generally ~ -0.2 – 0.2, with slope errors of the order of the slope, indicating no bias with measurement value. Statistical analysis using the QDEC tool within FreeSurfer indicates that areas with significant thickness and volume differences between the two scans are localized to a few key regions, especially the central gyri for thickness measurements (Fig. 2).

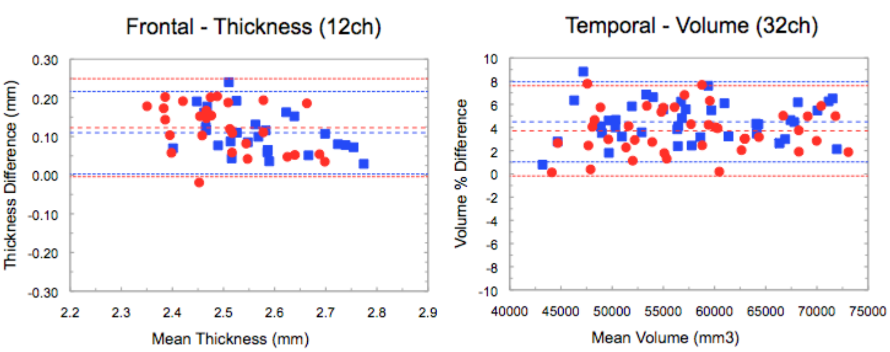

Fig. 1: Bland-Altman difference plots for frontal lobe thickness in the 12-channel group, and temporal lobe volume in the young-adult 32-channel group. Blue = left; red = right hemisphere. Dashed line = mean difference, dotted lines are 2×std-dev confidence limits.

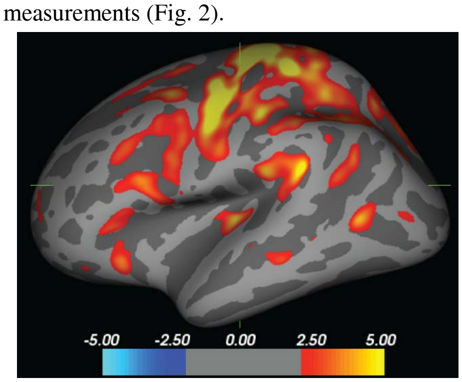

Fig. 2: Statistical analysis of thickness differences between the p2 and p4 scans in the young-adult 32-channel group. Color bar indicates *t*-test values.

Discussion/Conclusion: Although volume determinations for sub-cortical/white matter structures validate well between the p2 and p4 scans,[4] we now show that cortical thickness/gray matter volumes show a small but sometimes significant bias to the p2 scan. Correlations, however, remain high, indicating that any bias is not random but rather due to an experimental systematic. This is possibly related to the variation in TI and TR between the two scans. The p2 scan uses the FreeSurfer-recommended values, while the p4 scan, in order to decrease scan time, reduced these values slightly from the recommended ones. These effects will be the subject of future study. FreeSurfer analysis is generally expected to not perform as well on elderly subjects due to atrophy effects. However, these results show that good correlation can still be obtained for cortical morphometric results between the scan protocols on elderly subjects, while bias is of a similar order to that seen for healthy young adults.

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References

1. Han X, et al., Reliability of MRI-derived measurements of human cerebral cortical thickness: The effects of field strength, scanner ... *NeuroImage* 2006:32; 180–194.
2. van der Kouwe AJW, Benner T, Salat DH, Fischl B, Brain morphometry with multiecho MPRAGE. *NeuroImage* 2008;40:559–569.
3. Mair R, et al., Quantitative Reliability for Extremely Rapid Structural Data Acquisition Across Time, Scanners, and Software Upgrade. *Proc ISMRM* 2011;19:2356.
4. Mair R, et al., Quantitative Comparison of Morphometric Data from Multi-Echo MPRAGE with Variable Acceleration and Different …. *Proc ISMRM* 2013;21:947.
5. Fischl B, Measuring the thickness of the human cerebral cortex from magnetic resonance images, *Proc. Natl. Acad. Sci. USA*, 2000:97, 11050-11055.
6. Reuter M, Highly Accurate Inverse Consistent Registration: A Robust Approach, *NeuroImage*, 2010:53;1181-1196.
7. surfer.nmr.mgh.harvard.edu/fswiki/CorticalParcellation