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Reliability in Multi-Site Structural MRI Studies: Effects of gradient non-linearity correction on volume and displacement of brain subcortical structures

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Introduction: In studies where morphological MRI data is pooled across sites it is extremely important to characterize and minimize site-specific MRI image distortions factors to allow accurate cross-site comparisons of morphometry results. In previous work (Jovicich et al. 2003), a phantom study showed how non-linearities in the imaging gradient fields cause strong geometric distortions (displacements), which vary widely across FOV and across gradient models/vendors, also showing how these distortions can be significantly reduced thereby improving multi-site reproducibility. Here we extend our work to study the effects of distortion correction on brain subcortical data. Specifically, we performed both a prediction and an empirical study of how distortion correction affects the volume and displacement of subcortical structures in a group of subjects scanned at multiple sites.

Methods: Image distortion characteristics [GE Signa (3-sites) and Siemens Sonata (1-site), all 1.5T] are accurately characterized by manufacturer-supplied spherical harmonics coefficients of the MR gradient fields (Jovicich et al. 2003). Prediction Study: An arbitrary volume (segmented hippocampus from a healthy volunteer) was used to predict the magnitudes of the volume changes and displacement effects introduced by the distortion correction, as a function of the location of the volume within the FOV. For each of the 4 sites investigated, the volume was parametrically moved within the FOV of the characteristic displacement field. At each position the volume was distortion corrected and the resulting correction multiplicative factor and mean magnitude of the volume's post-correction displacements were mapped. Empirical Study: 6 normal controls were scanned at the 4 sites (3D-spoiled gradient echo, TR=20ms, TE=6ms, 256x192, 1.5mm thick 124 sagittal slabs, flip angle=30^0). Subcortical brain segmentations were obtained from the original MRI data (Fischl 2002). Volume correction factors and mean displacements were calculated from the characteristic displacement fields for each corresponding site. An ANOVA was performed to test for site, session and structure effects.

Results and Discussion: The prediction study shows that, within the space where the head may be positioned in the gradient field, a structure like hippocampus can have up to 10% error in its uncorrected volume, with a post-correction mean displacement of up to 4 mm. Both magnitudes increase fairly rapidly moving away from the gradient's iso-center. The empirical study shows that most subcortical structures had volume correction errors of the order of 3%, with displacements under 1mm. Strong site and subject effects were observed, directly related to how far away from the iso-center the imaging session was. Preliminary results show that distortion correction reduces the group variance in the volume estimates (up to 8% improvement for hippocampus). This work will continue to evaluate test-retest reproducibility.

References:

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