Test retest reproducibility assessments for longitudinal studies: quantifying MRI system upgrade effects

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INTRODUCTION

- **Background**: Neuroimaging longitudinal studies of change over time are becoming increasingly a standard element of clinical neuropsychiatric research [1,2].
- **Limitation**: Technical advances, typically system upgrades, introduce technology related variability in the images that limits the power for following the progression of disease.
- **Motivation**: Develop and apply procedures that both [3] standardize acquisition parameters over time and estimate and correct for the error introduced by uncontrolled factors.
- **Goal**: We took the opportunity of an MRI system upgrade (1.5 T Siemens, from Sonata to Avanto) to investigate the reproducibility of a structural morphometry protocol before, after and across the upgrade. To make the results independent of brain morphometry tools, here we focus only on the reproducibility of image intensity.

METHODS

MRI System upgrade changes (Siemens)

- Main 1.5T Magnet (length): Avanto (150 cm), Sonata (160 cm)
- Magnetic Gradient System: Avanto (45 mT/m @ 200 T/m/s)
  Sonata (40 mT/m @ 200 T/m/s)
- Head RF Coil: Avanto (12 channel), Sonata (CP)
- Software

Standardization of structural MRI protocol

- We evaluated the reproducibility of two 3D structural MRI acquisition protocols that give good gray/white matter contrast and that can be used for automated brain morphometry.
- For both Sonata & Avanto platforms, brains were automatically aligned to an atlas in each scanning session [4,5].
- MP-RAGE: Two 3D Sagittal, TR/TE/TI = 2.73s/3.44ms/1s, 256x192, 1.33mm thick slices, 128 sagittal slabs, flip angle= 7^0
- Multiple flip angle FLASH: 3D Sagittal, TR/TE=20ms/6ms, 256x192, 1.33mm thick slices, flip angles 30^0 and 5^0
- Subjects: 5 volunteers scanned twice on each system. Each subject has 4 summary MP-RAGE scans and 4 summary FLASH scans (next point): Sonata1, Sonata2, Avanto1, Avanto2.

Image pre-processing

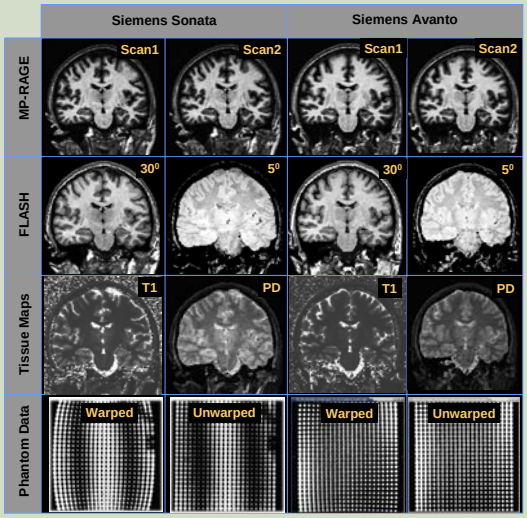
- MP-RAGE scans: co-registered and averaged
- FLASH scans: T1 and proton density (PD) maps derived from the two co-registered flip angles using the Bloch equations. A synthetic image optimally weighted to maximize gray/white matter contrast-to-noise ratio is derived from the tissue maps [6]
- The Montreal Neurological Institute tools were used for image co-registration.
- Distortion corrected (unwarped) volumes obtained using gradient's specific non-linearity properties [3]

Test-retest reproducibility evaluation

- Pre-processed images are skull stripped [7]
- Paired test-retest scans are co-registered and normalized to have the same overall mean intensity
- For each subject calculate image intensity variability:
  - o Paired test-retest cases:
    [Sonata1-Sonata2], [Avanto1-Avanto2], [Sonata1-Avanto1],[Sonata2-Avanto2]
  - o Voxel-based relative error maps
  - o Global brain mean value from each variability map
  - o Repeat all the above with and without distortion correction

RESULTS

Sample Structural and Distortion data



Sample Intensity Variability Maps

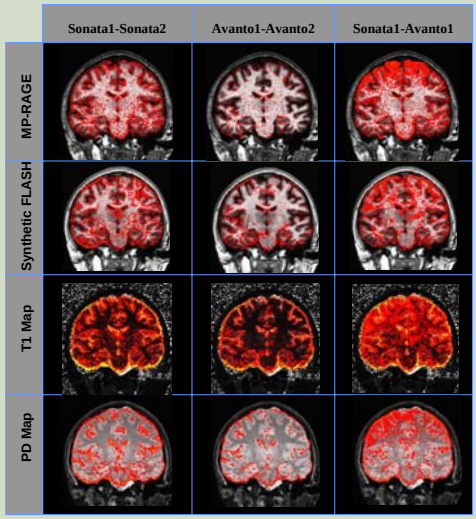
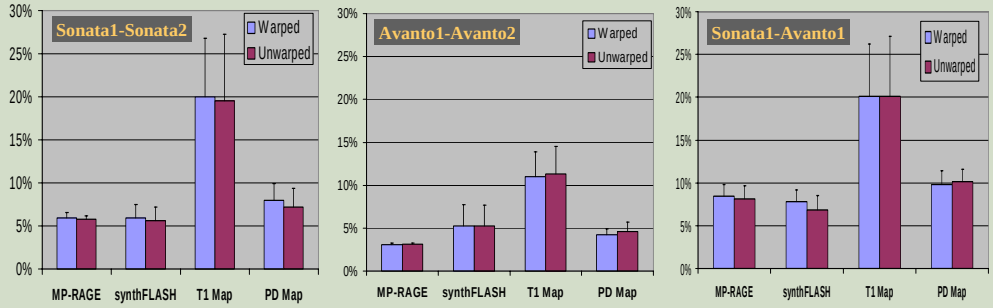


Image Intensity Variability Measures

(averages across subjects, means and std)



CONCLUSIONS

- **Image intensity reproducibility**:
  - o System effects: Avanto overall better than Sonata (upgrade welcome)
  - o Unwarping effects: Marginal improvements. Does not explain Avanto & Sonata differences. Unwarping effects slightly larger in Sonata (gradients less linear)
  - o Sequence effects: Synthetic FLASH data seems slightly more consistent across the upgrade than MP-RAGE (probably due to dependency on tissue maps, which should be less dependent on hardware after calibration). The high intensity variability in the tissue maps could be due to image noise effects on the non-linear parameter fit to derive the maps.
  - o Analysis effects: variability stronger in CSF-gray matter boundary areas.
- **Next steps**:
  - o Add correction of more sources of variability: B1 inhomogeneity
  - o Add reproducibility metrics: cortical thickness and subcortical volumes

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