Repeatability and reproducibility of cortical thickness using DiReCT and the CaliBrain sMRI data

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Introduction:

Cortical thickness is an important biomarker in image-based studies of the brain. A number of techniques have emerged that estimate this thickness (Das et al, Hutton et al, Jones et al) but none have reached the status of “gold standard”. This, combined with the increased interest in multicentre structural magnetic imaging studies (sMRI), led us to investigate the repeatability and reproducibility of cortical thickness determined using a diffeomorphic registration based method (DiReCT) (Das et al).

Methods:

- Fourteen healthy participants (10 male, mean age 36.3 yrs) scanned on two occasions, two weeks apart, on 3 General Electric 1.5T scanners.
- High resolution 3D T1-weighted scans (TR=5.9ms, TE=1.9ms, TI=600ms, thickness=1.7mm, inplane voxel size 0.86mm) (Figure 1).
- SUSAN nonlinear noise reduction (Smith et al, 2000) (Figure 2).

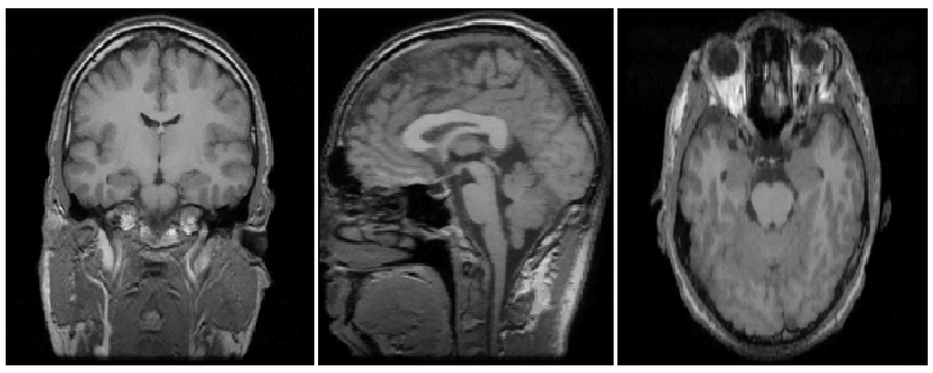

Figure 1: Example inversion-recovery prepared fast gradient echo image

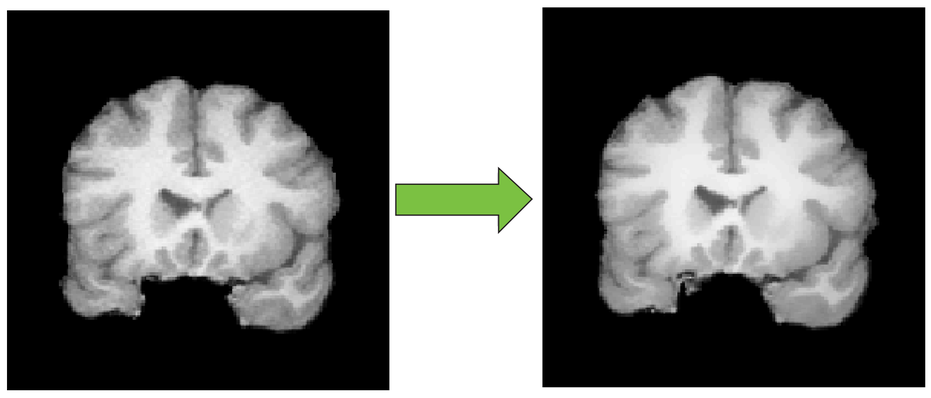

Figure 2: Results of performing SUSAN de-noising on T1 weighted structural data

- Segmentation using the standard SPM8 segmentation process (http://www.fil.ion.ucl.ac.uk/spm/).
- Voxel based cortical thickness determined from original scan and SUSAN de-noised version using DiReCT, as implemented in the Advanced Normalization Tools (ANTS) toolbox (http://picsl.upenn.edu/ANTS/). (Figure 3).
- Normalisation to the standard SPM8 T1 template.
- Variability of mean cortical thickness determined in the frontal, temporal, parietal and occipital lobes and limbic regions (VOIís generated with wfu_pickatlas).
- Repeated measures analysis using SPSS 17.
- Voxel based analysis using full factorial design in SPM8, 2 factors (visit x 2, site x 3).

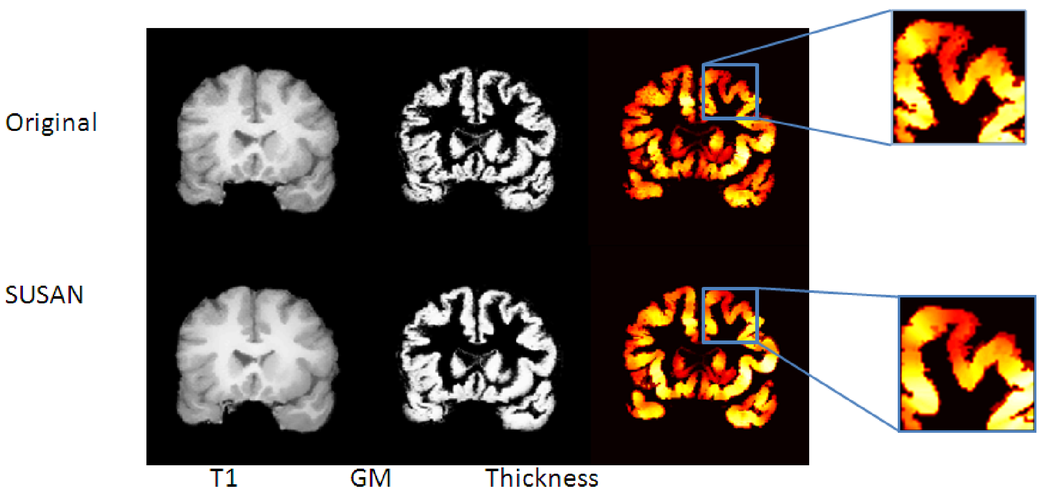

Figure 3: Pre-processing steps to produce cortical thickness measures

Results:

- Figures 4 and 5 show the mean lobar cortical thickness measurements for all sites before and after SUSAN de-noising.

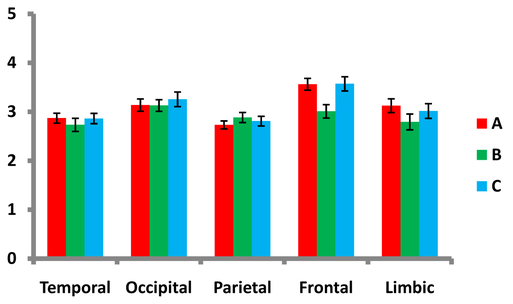

Figure 4: Mean lobar cortical thickness averaged across visits for the original data

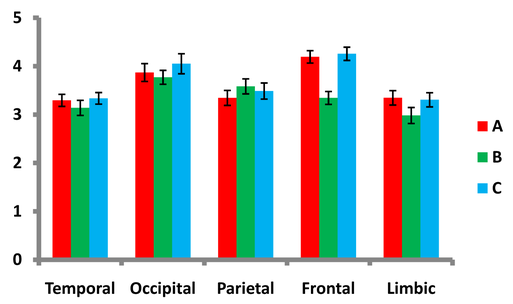

Figure 5: Mean lobar cortical thickness averaged across visits for the SUSAN de-noised

- No significant effect of visit on any of the tests on cortical thickness measures.
- Significant main effect of site for:
  - Frontal lobe original F(1,14)=3.48, p<.05;
  - Parietal lobe original F(1,14)=4.63, p<.05;
  - Temporal lobe original F(1,14)=47.18, p<.05;
  - Occipital lobe SUSAN de-noised F(1,14)= 5.55, p<.05;
  - Parietal lobe SUSAN de-noised F(1,14)=4.86, p<.05;
  - Temporal lobe SUSAN de-noised F(1,14)=76.72, p<.05.

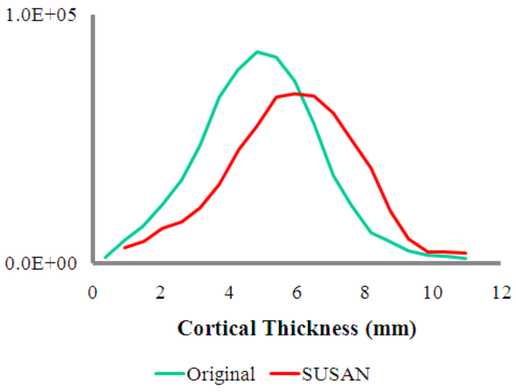

Figure 6: Voxel based estimates of the effect of scanner site on the estimation of cortical thickness.
A) original data, B) SUSAN de-noised data

- No significant interaction between site and visit.
- Significant difference in cortical thickness between original and de-noised data was found for all regions, e.g. frontal region, site A (t=2.60, p=.01).
- Reduced between site variability of cortical thickness following image de-noising. (Figure 6)

Conclusions:

- By applying a de-noising filter (SUSAN) to multi-centre structural data we can reduce the large areas of significant between scanner variability in cortical thickness.
- Although SUSAN is described as a structure preserving de-noising algorithm the de-noising procedure resulted in a significant increase in calculated cortical thickness over the whole brain.
- Investigation of the individual sources of variation suggest that scanner B shows significant differences when compared with scanners A and C.
- Moorhead et al (2009), propose the use of scanner specific segmentation priors to further minimize scanner specific variations, that combined with de-noise filtering may provide a mechanism to reduce “between” scanner variability to the level of “between” subject variability.

Lay Summary:

Multi-centre studies assume that data from two or more centres can be combined and that there is no effect of the site on the results. This assumption was tested for a measure of cortical thickness, or the depth of the grey matter layer on the surface of the brain. Magnetic resonance Imaging (MRI) was used to create a high resolution brain images that allowed the grey matter thickness to be measured. We compared the original images with images that had noise removed. The results showed that there was a significant difference between sites when measuring the cortical thickness of the same individual measured on different MRI scanners. This difference was reduced when noise was removed from the images.

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References:

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