Cerebral asymmetry: A voxel based morphometry study of 465 normal adult brains

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Introduction

In this study, we apply voxel based morphometry, a fully automated whole brain morphometric technique(1), to a large sample of in vivo MR image volumes from normal adult subjects (n=465). We characterise and quantify human brain asymmetry and document the effects of sex and handedness on cerebral asymmetry.

Methods

Magnetic resonance imaging was performed on a 2 Tesla Siemens scanner. A 3D structural MRI was acquired on each subject using a T-1 weighted MPRAGE sequence (TR/TE/TI/NEX 9.7/4/ 600/1, flip angle 12°, matrix size 256 x 192, FOV 256 x 192, yielding 108 sagittal slices, slice thickness of 1.5mm and in plane resolution of 1mm x 1mm. Data were analysed on a Sun Ultra 60 workstation using MATLAB 5.3 and SPM 99(2).

We created customised, symmetric grey and white matter templates derived from 120 constituent images chosen pseudorandomly from the group, matched for handedness and age. We used an optimised method of pre-processing for VBM, which includes a fully automated procedure to remove scalp tissue, skull and dural venous sinus voxels from the structural images; affine and non-linear normalisation to grey and white matter templates; segmentation and a modulation step to incorporate information from the spatial normalisation deformation fields. Finally we smoothed each image with a 12mm FWHM isotropic gaussian kernel. We conducted 2 ´ 2 ´ 2 (flipped/unflipped by sex by handedness) factorial analyses for grey and white matter and CSF respectively to assess brain asymmetry and the effects of sex and handedness. We performed conjunction analyses to detect common asymmetry effects. Regionally specific differences in grey matter, white matter, and CSF between groups were assessed statistically using a two-tailed contrast, namely testing for an increased or decreased probability of a particular voxel being grey or white matter or CSF respectively. In order to examine regional differences, we controlled for global differences in voxel intensity across scans by including the global mean voxel intensity value as a confounding covariate. Significance levels for the F statistics were set at $p<0.05$, corrected for multiple comparisons.

Results

We detected extensive grey matter asymmetry common to all subjects (conjunction analysis), namely larger left occipital, right frontal and right temporal lobes (the so-called petalia). Furthermore, we detected more focal leftward (left > right) asymmetry in the transverse temporal (Heschl's) gyri, frontal operculum, in the depths of the superior and inferior frontal sulci, mesial temporal lobe (including amygdala and hippocampus), anterior cingulate sulcus, caudate head and medial cerebellum. Focal rightward (right>left) asymmetry was seen in the lateral thalamus, around the calcarine sulcus, anterior cingulate and in the lateral cerebellum. There was a significant interaction of sex with asymmetry at the medial end of Heschl's sulcus, at the junction with PT, with males having increased leftward asymmetry. There was no interaction of handedness with asymmetry. White matter and CSF asymmetries were also observed.

Discussion

Our data replicate many well established post-mortem and in vivo findings of human brain structural asymmetry, whist expanding on regional details. The use of large numbers of subjects facilitated the examination of relatively subtle effects, whilst highlighting the need for a rigorous and optimal VBM method to avoid errors caused by miss classification of non-brain voxels.

References

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