HCP Structural and Diffusion Data Methods

Introduction

The Human Connectome Project has released structural and diffusion scans from 35 healthy adult subjects. Imaging protocols and processing methods are described below.

Imaging Protocols

Each dataset (in NIfTI format) consists of an MPRAGE scan, a high resolution T2-SPACE scan and diffusion scans with 4 different b-values.

Structural Scans

Type	T1w	T2w
Description	3D MPRAGE	3D T2-SPACE
TR/TE (ms)	2530/1.15	3200/561
TI (ms)	1100	
Flip Angle	7.0 deg	
FOV (mm)	256x256	224x224
Voxel Size	1mm isotropic	0.7mm isotropic
BW (Hz/Px)	651	744
iPAT	2	2
Acquisition Time (min:sec)	6:02	6:48

Diffusion Scans

Parameter	Value
Sequence	Spin-echo EPI
TR/TE (ms)	8800/57
echo time/ diffusion time (ms)	12.9/21.8
FOV (mm)	210x210
Matrix	140x140
Slices	96 slices, 1.5mm thick, 1.5mm isotropic voxel size
iPAT	3
Multiband factor	1
Echo spacing (ms)	0.63
BW (Hz/Px)	1984
Phase Partial Forier	6/8
b-values (s/mm2)	1000, 3000, 5000, 10,000
Total acquisition time (mins)	89

Structural scans were reviewed by a radiologist to assure absence of brain abnormalities.

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Diffusion data were acquired in oblique axial slices. Diffusion gradients are mono-polar. The echo time and diffusion times were optimized for the b-value=10,000 (s/mm^2) shell, and fixed for all the lower b-value shells. Diffusion scans are comprised of 5 runs:

Run #	b-value (s/mm2)	Diffusion Directions	Acquisition time (min:sec)
1	1,000	64	11:44
2	3,000	64	11:44
3	5,000	128 (set 1)	21:51
4	10,000	128 (set 1)	21:51
5	10,000	128 (set 2)	21:51

One non-diffusion weighted (b=0) image was collected every 14 image volumes, yielding 552 volumes in total. Phase encoding direction was anterior to posterior. Multiband acquisition was not used in this dataset.

Data Preprocessing

Imaging data was processed with software tools in FreeSurfer v5.3.0 and FSL v5.0.

Structural Scans

1. Gradient nonlinearity correction. The distortion caused by the gradient nonlinearity was corrected based on the spherical harmonic coefficients.
2. De-face and De-ear. A face mask was generated using the FreeSurfer tool. The ear masks were drawn manually. These masks were then used to mask off the facial and ear regions on the MPRAGE and T2-SPACE images.

Diffusion Scans

1. Gradient nonlinearity correction.*
2. Motion Correction. The b=0 images interspersed throughout the diffusion scans were used to estimate the bulk head motions with respect to the initial time point (first b=0 image), where the rigid transformation were calculated with the boundary based registration tool in the FreeSurfer package v5.3.0 (Greve and Fischl, 2009). For each b=0 image, this transformation was then applied to itself and the following 13 diffusion weighted images to correct for head motions. After motion correction, the b-vectors were adjusted according to the rigid rotation estimated.
3. Eddy current correction. The FSL's 'EDDY' tool (Andersson et al., 2012) was to correct for eddy current distortion. All 4 shells (bvals = 1k, 3k, 5k, 10k s/mm2) were concatenated (552 volumes in total), and passed into the EDDY tool.
4. b-vectors. After eddy current correction, the rigid rotational motion estimates obtained from both the motion correction step and the eddy current correction step were concatenated and applied to the original b-vectors for correction.

* Both diffusion and structural data are provided in native space. Since the gradient field nonlinearity coefficients were protected by Siemens as proprietary information, the ep2d diffusion gradwarped and T1w/T2w scans were already corrected for gradient nonlinearity.

References

Andersson, J.L., Xu, J., Yacoub, E., Auerbach, E., Moeller, S., Ugurbil, K., 2012. A comprehensive Gaussian Process framework for correcting distortions and movements in diffusion images. Proc Intl Soc Mag Reson Med, p. 2426.

Greve, D.N., Fischl, B., 2009. Accurate and robust brain image alignment using boundary-based registration. Neuroimage 48, 63-72.