# An Unsupervised Group Average Cortical Parcellation using HARDI data

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**Introduction:**

Cortical parcellations provide valuable localisation tools for other modalities such as fMRI as well as information regarding the relationship between the structure and function of the brain. Traditional approaches such as the Brodmann map [1] are limited to single subject data and do not account for intersubject variability[2], thus an in-vivo solution to this problem is desirable. Diffusion MRI (dMRI) is primarily used to investigate white matter structures in the brain, however, recent studies have demonstrated that diffusion anisotropy is present and varies heterogeneously between different cortical grey matter (GM) regions [1,4,6,7]. In particular [7] demonstrated the discriminative power of a feature set derived from high angular resolution diffusion imaging (HARDI) data by testing on distinct fMRI based regions of interest (ROI) on single subjects. This work expands on these findings, using HARDI data of multiple subjects to produce an entirely unsupervised, hemisphere-wide, group average parcellation in which anatomically meaningful clusters are present.

**Methods:**

Data were provided by the Human Connectome Project, WU-Minn Consortium (Principal Investigators: David Van Essen and Kamil Ugurbil; 1U54MH091657) funded by the 16 NIH Institutes and Centers that support the NIH Blueprint for Neuroscience
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The diffusion weighted images (b=1000,2000,3000s/mm$^2$, 1.25mm isotropic) of 17 unrelated subjects (10m, 7f, aged 22-35) was sampled onto each subjects GM/WM boundary surface and fit with a spherical harmonic series (SHS) up to the 6th order, as detailed in [7]. A subset of the features introduced by [7] are taken to obtain a 1x15 feature vector based on the SHS at each vertex point of the cortical surface. Each of the 15 features is sampled onto the fsaverage Freesurfer surface and then averaged across all 17 subjects according to the surface based averaging approach of [5]. Finally, the 15 averaged feature vectors are recombined into a single feature set and k-means classification is used to segment the entire hemisphere into k=150 clusters.

**Results:**

Fig.1 shows the lateral surface of the right hemisphere parcellation using the population average feature set. Two areas within the central sulcus corresponding to the architectonically distinct primary somatosensory (S1) and primary motor (M1) cortices are emergent (A). In addition, coherent clusters are present in a location that is consistent with Broca's area in the opercular cortex (B) and a set of smaller clusters (blue/purple/green) corresponding to the location of the primary and "belt" auditory areas (D) can be observed. Also visible is a distinct orange cluster overlapping the expected location of the middle temporal visual area (MT), which is known to be heavily myelinated (C).

Fig.2 shows the medial surface of the same result as Fig.1. Here, the entire occipital lobe appears in similar colours (purple/blue) possibly reflecting the heavy myelination of this region. Within the

occipital lobe, the most salient feature is the red cluster (B) which is consistent with the location of the upper vertical meridian of the primary visual cortex. In addition, we observe clusters that end near the border of S1 and M1 on the medial surface (A).

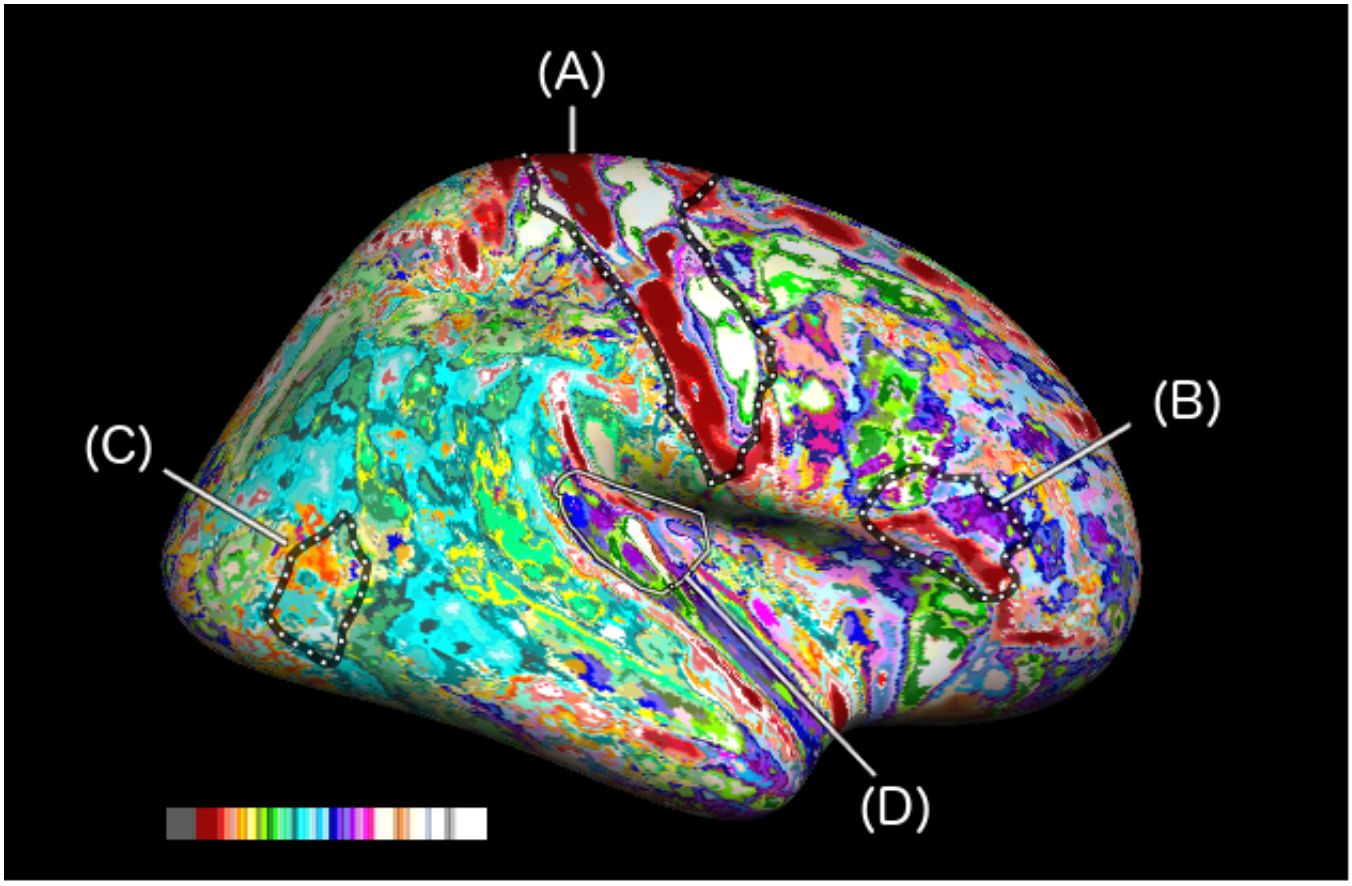


**Figure.1**: Lateral surface k-means clustering result of 17 subject group average feature set on the right hemisphere (k=150). Clusters are ordered by similarity of cluster centres such that similar clusters are displayed in alike colours. Dashed lines (▬▬▬) show Freesurfer probabilistic Brodmann area labels of several regions. Solid line (═══) is a manually drawn contour.
**(A)** The primary somatosensory (red) and primary motor (white) cortices within the central sulcus. The boundary shows the extent of the atlas labels onto the surrounding pre/post central gyri.
**(B)** Clusters in the opercular cortex (red/purple/green) roughly corresponding to the atlas label for Broca's Area. The boundary shows the BA45 atlas label with a lower threshold value of 0.3.
**(C)** Orange cluster partially overlapping the expected location of the middle temporal visual area (MT/V5). The boundary shows the MT atlas label with lower threshold of 0.2.
**(D)** Series of clusters in the estimated location of the primary auditory cortex and "belt" auditory areas.

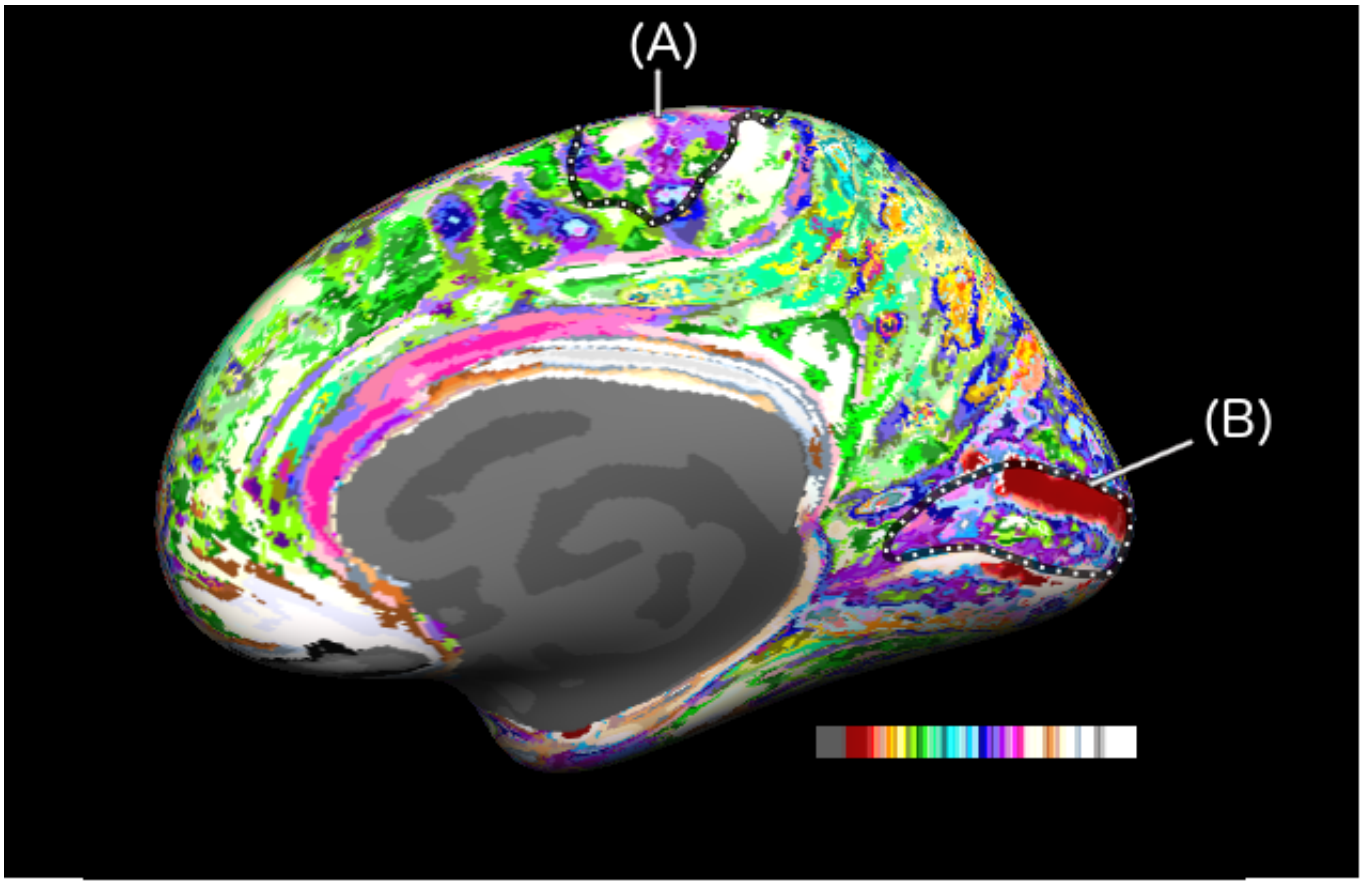


**Figure 2**: Medial surface k-means result of 17 subject group average feature set on the right hemisphere (k=150). Clusters are ordered by similarity of cluster centres such that similar clusters are displayed in alike colours. The grey area in the centre contains vertices which were not included in the clustering. Dashed lines (- - - - - -) show Freesurfer probabilistic atlas labels.
**(A)** Medial extensions of primary somatosensory and primary motor areas (purple/white). The boundary shows the extent of the atlas labels for Brodmann areas 3a,3b,4a and 4p.
**(B)** Distinct red cluster which is consistent with the upper boundary of the primary visual cortex (V1). The boundary marks the atlas label for V1.

**Conclusions:**

We presented a parcellation result using dMRI data, demonstrating areal definitions which reflect some well known architectonically defined regions. The population average feature set is most discriminative in primary areas which are consistently located across subjects, such as S1 and M1, and heavily myelinated regions. However, we also observe clusters which may correspond to non-primary areas such as Broca's Area. Results suggest these higher order features are associated with the local texture/geometry of myelinated meshwork and may provide additional information to myelin maps. Future work aims to refine the feature set and clustering approach.

**Imaging Methods:**

Diffusion MRI

**Informatics:**

Brain Atlases

**Modeling and Analysis Methods:**

Diffusion MRI Modeling and Analysis [2]

Segmentation and Parcellation [1]

**Neuroanatomy:**

Cortical Cyto- and Myeloarchitecture

**Keywords:**

Cortex

Modeling
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Segmentation
Other - HARDI

*[1|2]Indicates the priority used for review*

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Not applicable

**Please indicate which methods were used in your research:**

Diffusion MRI

**Provide references in author date format**

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