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# A Novel Parcellation of Human Cerebral Cortex based on Extrinsic Connectivity

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# A Novel Parcellation of Human Cerebral Cortex based on Extrinsic Connectivity

## 1 Introduction

Current theories hold that the human cortex can be subdivided in anatomically and functionally distinct regions, from which interactions cognition arises. In these interactions the long-range axonal connectivity, namely extrinsic connectivity, plays a fundamental role (Passingham et al., 2002). Hence, parceling the cortex taking into account its extrinsic connectivity can help to understand brain’s internal organization. However, current brain atlases are based on cytoarchitecture (Brodmann, 1909) or anatomical landmarks (Desikan et al., 2006), which do not necessarily reflect brain’s connectivity. Even modern approaches, like that of Glasser et al. (2016) did not include connectivity information on their building process. Using such parcellations on studies involving connectivity could introduce a bias, leading to erroneous connections and conclusions.

In Gallardo et al. (2016) we presented a hierarchical clustering based technique to parcellate the whole cortex based on its extrinsic connectivity. In this work, we show the consistency of our technique. Then we use it to obtain a novel cortical 55 parcels parcellation based on the extrinsic connectivity of 138 subjects from the Human Connectome Project (HCP). Experiments show that several of our extrinsic parcels are closely related to brain functionality.

## 2 Methods

A total of 138 subjects (65 males and 73 females, ages 31-35) were randomly selected from the group S500 of the Human Connectome Project. Each subject was already preprocessed with the HCP minimum pipeline (Glasser et al., 2013) and have a coregistered dense mesh (32k vertices per hemisphere) representing they cortical surface Glasser et al. (2013). For each subject, we performed probabilistic tractography by simulating the movement of 5000 water particles from the vertices of they mesh. Later, we computed every seed-vertex’s tractogram by calculating the fraction of its particles that visited each other seed-vertex.

We randomly divided our HCP subject sample in 3 disjoint groups of 46 subjects each, trying to maintain the same proportion of males and females. Then, we computed each group’s groupwise parcellation using our hierarchical clustering based technique Gallardo et al. (2016). To assess the consistency of our parceling technique, we compared the obtained parcellations at every level of granularity using the adjusted Rand index (Hubert and Arabic, 1985). We generated a baseline by computing the similarity between random homogeneous parcellations of the cortex.

After assessing the consistency of our technique, we computed a groupwise parcellation from the 138 subjects’ connectivity. Since the 55 parcels granularity showed a high average similarity when comparing the 3 disjoint groups, we used it also for the 138 subject’s parcellation.

## 3 Results

Figure 1.a shows that the similarities between the left-cortex parcellations of 3 disjoint groups (lines red, green and blue) are significantly higher for all granularities when compared with the null case of randomly-generated parcellations (violet). Figure 1.b shows the parcellation of each group at 55 parcels of granularity. Figure 2.a shows the parcellation obtained from 138 subjects at 55 parcels of granularity for both hemispheres. Figure 2.b shows a projection of some of our parcels over z-score maps representing average activations to functional tasks from the Unrelated100 HCP population. Figure 2.c shows that all the parcels in fig. 2.b contain a higher proportion of positive values than negative ones. Furthermore, the high proportion of z-score higher than 5 show that those parcels are highly related to some functional task.

## 4 Conclusions

In this work we showed that our technique creates groupwise parcellations consistent across groups. Then, we used it to create a parcellation using 138 subjects. Our purely extrinsic parcellation

showed good agreement with functional parcellations, i.e. the human homunculus. The obtained parcellation and related tools are available at: [http://gagdiez.github.io/EC\\_atlas](http://gagdiez.github.io/EC_atlas).

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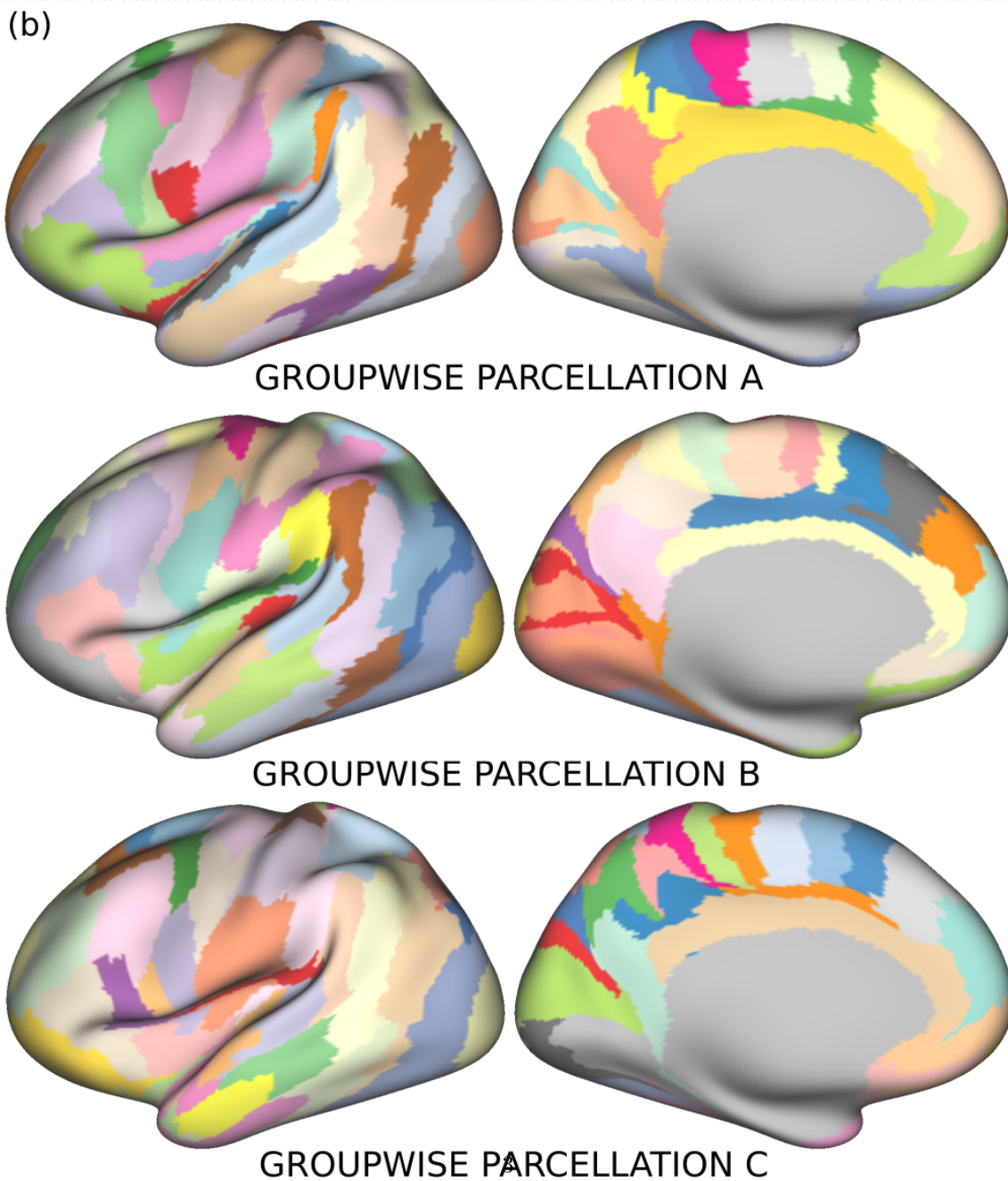
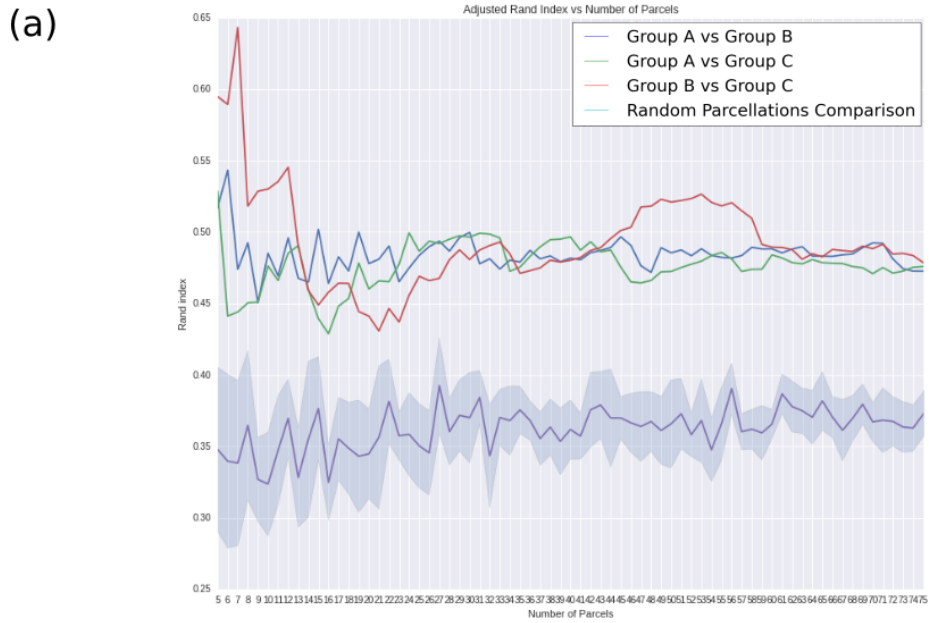


Figure 1: (a) Adjusted Rand Index obtained when comparing: (red) Group A vs Group B; (blue) Group A vs Group C; (green) Group B vs Group C; (purple) Baseline from random homogeneous parcellations. (b) Groupwise parcellations of 3 disjoint groups of 46 people each, the parcellation possess 55 parcels.

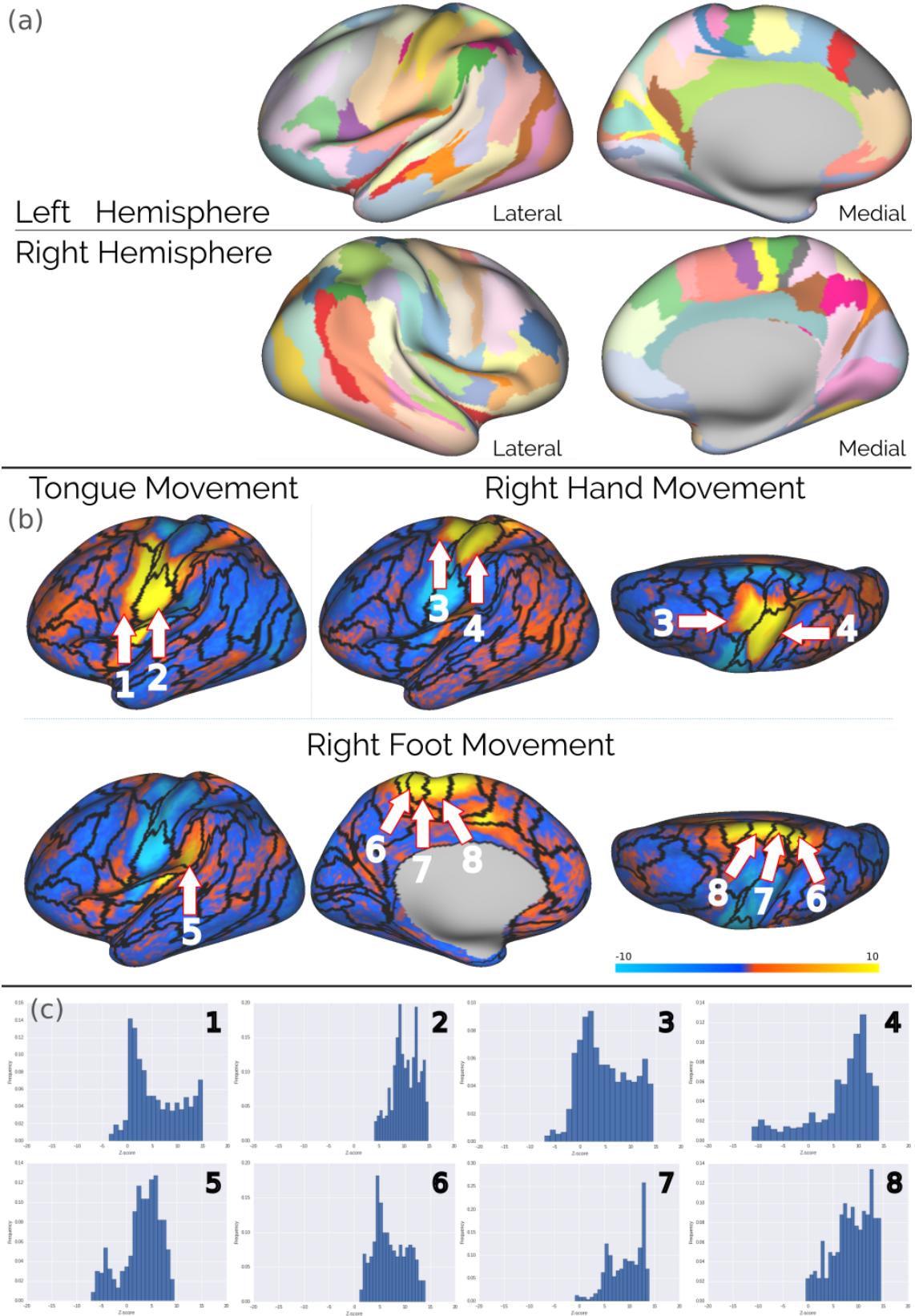


Figure 2: (a) Groupwise parcellation with 55 parcels per hemisphere, computed from the extrinsic connectivity of 138 subjects in the Human Connectome Project. (b) Our left groupwise parcellation projected over z-scores representing activations during hand, foot and tongue movement. (c) Histograms showing the distribution of z-score inside our left parcels. The null or small fraction of negative values shows the functional specialization of our parcels