Contribution ID: **17** Type: **Poster**

Multimodal gradients reveal cortical local-global organization

Thursday 5 October 2023 16:30 (45 minutes)

Functional specialization and integration of the human cortex are two basic principles in neuroscience. For decades, significant efforts have been made to explore the underlying mechanisms of these principles based on a broad range of neuroanatomical and neuroimaging features. However, the spatial patterning of cortical organization and the interrelationships between different regions are still unclear. Recent studies have derived low-dimensional, continuous representations of cortical organization, also referred to as gradients, using cortex-wide decompositions of functional, microstructural, and structural connectivity features. The current work characterizes functional, microstructural, and structural gradient features within the probabilistic atlas of cortical cytoarchitecture, and assessed the uniqueness and redundancy of gradient profiles across cytoarchitecturally-defined cortical areas.
In this work, we studied 7 Tesla (7T) T1-weighted Magnetic Resonance Imaging (MRI), resting-state functional MRI, myelin-sensitive quantitative T1, and diffusion MRI of 10 unrelated healthy adults. Specifically, our work (i) took advantage of high-resolution 7T MRI to construct vertex-wise structural, microstructural, and functional connectomes, (ii) captured gradients profiles of brain regions through the integration of multimodal MRI and probabilistic atlas of cortical cytoarchitecture, (iii) assessed inter-parcel heterogeneity and homogeneity of multimodal features to quantify the uniqueness and redundancy of gradient fingerprints, and (iv) assessed intra-parcel heterogeneity between cortical vertices. To verify these findings, we repeated the main analyses on an independent dataset with 50 healthy adults.
Vertex-wise gradients of multimodal MRI data showed different spatial patterns across the cortex, indicating diverse hierarchies between vary modalities. By estimating cosine similarity between cortical regions, we found higher homogeneity in paralimbic regions and lower homogeneity in idiotypic i.e., sensory and motor cortices. To examine inter-parcel heterogeneity, we computed cosine distance between parcel-wise gradient profiles. We observed the highest heterogeneity in primary sensorimotor cortices, and lowest heterogeneity in paralimbic network ($p<0.05$, FDR corrected). Finally, we found that for most cortical parcels, vertices within a parcel are homogenous and show similar patterns among multimodal gradients. However, higher intra-parcel heterogeneity was found in heteromodal system ($p<0.05$, FDR corrected), while lower heterogeneity was found in idiotypic and paralimbic systems ($p<0.05$, FDR corrected). We repeated the main analysis on the validation dataset and found similar results.
Our findings point to a sensory-paralimbic differentiation of cortex-wide gradient fingerprints, where sensory/motor regions being more heterogenous compared to less distinctive paralimbic cortices. By reconciling local and global cortical features, our work may provide new insights into the neuroanatomical basis of specialized and integrative cortical functions.

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Session Classification: Poster Session