NeuroResource

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Precision Functional Mapping of Individual Human Brains

Highlights

- Individual brain organization is qualitatively different from group-average estimates
- Individualized measures of brain function become reliable with large amounts of data
- Individuals exhibit distinct brain network topography and topology
- We release highly sampled, multi-modal fMRI data on ten subjects as a NeuroResource

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In Brief

Gordon et al. demonstrate advantages of conducting whole-brain fMRI research in individual humans using large amounts of per-individual data, which greatly increases reliability and specificity. This work illustrates new approaches for fMRI-based neuroscience that allow detailed characterization of individual brain organization.

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Precision Functional Mapping of Individual Human Brains

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SUMMARY

Human functional MRI (fMRI) research primarily focuses on analyzing data averaged across groups, which limits the detail, specificity, and clinical utility of fMRI resting-state functional connectivity (RSFC) and task-activation maps. To push our understanding of functional brain organization to the level of individual humans, we assembled a novel MRI dataset containing 5 hr of RSFC data, 6 hr of task fMRI, multiple structural MRIs, and neuropsychological tests from each of ten adults. Using these data, we generated ten high-fidelity, individual-specific functional connectomes. This individual-connectome approach revealed several new types of spatial and organizational variability in brain networks, including unique network features and topologies that corresponded with structural and task-derived brain features. We are releasing this highly sampled, individual-focused dataset as a resource for neuroscientists, and we propose precision individual connectomics as a model for future work examining the organization of healthy and diseased individual human brains.

INTRODUCTION

Over the past 30 years, functional magnetic resonance imaging (fMRI) and, more recently, resting-state functional connectivity (RSFC) fMRI studies based on the blood-oxygen-level-dependent (BOLD) signal have significantly advanced our knowledge of human brain function and organization. By spatially coregistering and combining data from dozens, hundreds, or even thousands of individuals, neuroscientists have been able to reliably identify central tendencies of both task-induced activation patterns (Martin, 2007; Petersen and Posner, 2012; Rugg and Vilberg, 2013; Wager and Smith, 2003) and the large-scale network organization of the brain (Beckmann et al., 2005; Power et al., 2011; Smith et al., 2009; Yeo et al., 2011). However, unlike structural MRI, which demonstrates clear clinical utility by describing the physical structure of individual brains, fMRI and RSFC research approaches have generally shied away from studying individuals, with the notable exception of studies focused on specific regions of the cortex using functional localizers (Kanwisher, 2017) or high-field imaging (Cheng, 2016) (though see Huth et al., 2016 for an alternative approach to studying individual brains). Instead, much of systems neuroscience has focused on examining the group-average brain. While group averaging has revealed many basic principles of functional brain organization, the lack of emphasis on understanding individuals means that clinical applications of fMRI and RSFC have been limited to presurgical functional mapping (Mitchell et al., 2013; Sunaert, 2006).