Parsing medial prefrontal cortex: A joint meta-analytic and graph-theoretic approach.

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Valuation effects are consistently observed in medial prefrontal and posterior cingulate cortex (mPFC and PCC). The spatial extent of these effects is mostly indistinguishable from the default mode network (DMN) in existing meta-analyses. However, little is known about how valuation effects fit within the broader functional architecture of mPFC and PCC, or whether that architecture is consistent or idiosyncratic across individuals. Here we complement a meta-analysis with fMRI-based graph theoretic approaches to subdivide mPFC and PCC at the single-subject level. Our results suggest the functional topography of mPFC has substantial variability across individuals. This highlights the potential usefulness of estimating brain effects at the individual level in this region, and points to limitations of aggregative methods such as coordinate-based meta-analysis in determining whether valuation and DMN effects emerge from common or separable brain systems. Our approach shows promise in addressing this issue through future manipulations of valuation.

Networks | DMN | Valuation

One of the main goals of human cognitive neuroscience is to be able to prescribe function to brain regions, either in isolation or in their communication with others. Among general regions of the brain, the medial prefrontal cortex (mPFC, located in the midline frontal portion of the brain) has been suggested to subserve the cognitive abilities that differentiate humans from other animals (Barbas & Garcia-Cabezas, 2016). Specifically, this region has been related to a variety of functions, including decision making (Bartra, McGuire, & Kable, 2013), memory encoding (Shacter, Addis, & Buckner, 2007), and default mode deactivation (DMN) (Yeo et al., 2011). While much has been discovered about this area in primates (Barbas & Garcia-Cabezas, 2016), the lack of direct measurements of neuronal activity makes this a tough area to record in humans, one that nowadays relies mostly on functional MRI (fMRI). Unfortunately, the mPFC is especially challenging to image, as the oxygen-related signal recorded by fMRI is contaminated by the oxygen in the sinuses (Logothetis, 2008). In addition, this area is subject to more idiosyncratic cortical folding than any other region (Zilles, Palomero- Gallagher, & Amunts, 2013), thus adding a level of complexity to the generalizable dissection of topographic functional roles within mPFC.

Studies of valuation have consistently shown functional overlap with DMN. Recent meta-analytic work has attempted to distinguish the brain areas belonging to each by examining the locus of peak activity across studies related to the behavioral features mentioned above (Bartra et al., 2013; Acikalin, Gorgolewski, & Poldrack, 2017). While this approach offers valuable information, it is subject to the quality of imaging in each study, as well as their corresponding differences in tasks used to examine choice. In addition, recent findings suggest that the functional topology of the brain is better understood by accounting for organizational idosyncrasies (Braga and Buckner, 2018; Yeo et al., 2018, Gordon et al., 2017, Gratton...).

Given the shortcomings of study-specific and cross-study analyses mentioned above, there is potential value in combining complementary strengths from both approaches. While my lab is primarily interested in the portion of mPFC dedicated to decision making, in order to bypass the heterogeneity in behavioral tasks, it might be best to disentangle the mPFC by focusing first on which of its sub-regions belong to resting-state DMN, and which do not. The advantage lies in that (1) all resting state scans are performed equally (the subject lies in the scanner with their eyes open), and (2) there is a high quality resource of resting state data provided by the Human Connectome Project. Focusing on resting state data has been successful in determining a number of neural phenomena, including disentangling auditory and visual attention areas (Tobyne, Osher, Michalka, & Somers, 2017).

This approach opens an opportunity to examine brain dynamics. For example, a region's function might depend on its connectivity at any given time with one brain community or another. An ever-growing trend in human neuroimaging has been to apply network statistics to tackle these functional challenges. One great advantage of network science is the ability to characterize connectivity in a way that allows for comparisons among individuals in a meaningful way (Garcia, Ashourvan, Muldoon, Vettel, & Bassett, 2018), thus letting us address the folding idiosyncrasies mentioned above. Therefore, I propose to use some of the statistics that we have learned in class to estimate intrinsic functional subdivisions of the mPFC at the individual subject level. Particularly, I would like to distinguish communities related to DMN from non-DMN, so that we can generate more informed topographic targets for future studies of decision making.

In this study, I try to address my question at 3 levels of granularity: 1) across the literature (meta-analysis), selecting a number of regions of interest (ROI) that show significant

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overlap and specificity between DMN and decision making; 2) full-brain connectivity of actual fMRI data, using a pre-specified brain atlas; and 3) characterizing the connectivity of surface vertices (small units of function that contain oxygen-dependent neural information across time) for the regions selected in step one. I performed the last two steps at an individual subject level for 3 subjects, hoping to find some commonalities among them. In this way, I attempted to extract functional topographical information from topological network features.

Results

Discussion

Methods

Results

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