Structural connectivity of a reward-based decision making network

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Background

The decision making network:

Decision making has been shown to recruit a distributed network of brain regions encompassing midbrain dopaminergic regions and their targets. Using a loss aversion task, Tom et al. (2007) identified a set of eight regions that were active for both potential gains and potential losses on this task; the midbrain, posterior cingulate, right and left frontal poles, right and left dorsolateral prefrontal cortices, ventromedial cortex and ventral striatum (Figure 1).

In humans, little is known about the structural connectivity of this network and its relation to functional connectivity. Understanding the normal pattern of connectivity in this network has implications for the study of impaired decision making in addiction and other disorders. A fine characterization of this network could help identify changes in the pattern of connectivity in the network using a noninvasive imaging modality and inspire targeted therapies for improved decision making.

We sought to characterize the structural connectivity of a network of brain regions known to be involved in decision making using white matter probabilistic tractography analyses.

Relationship between structural and functional connectivity measures:

Several studies have investigated the relationship of resting state functional connectivity using functional MRI data acquired while subjects rested and did not perform a task to structural connectivity using diffusion tensor imaging (DTI) (Hagmann et al. (2008), Greicius et al. (2009)). These studies have found a strong correlation between the connectivity measures using the two modalities.

To our knowledge this study is the first to use task-based fMRI connectivity methods for the functional connectivity measure for comparison with ROI-based probabilistic tractography applied to DTI data for the structural connectivity measure.

Besides looking at the consistency of connectivity across modalities in the decision making network, we also sought to investigate the relationship of structure and function in a large-scale network encompassing all regions in the brain.

Methods

Participants:
Two samples (S1 and S2) of young healthy participants (S1: N=21, 15 female, ages 18-30 and S2: N=48, 21 female, ages 17-26) underwent diffusion tensor imaging (DTI).

DTI data acquisition:
S1: 64 directions were acquired on a 3T Siemens Trio scanner at UCLA with the following parameters; TR/TE=7000/93 ms, 96x96 matrix, FOV, 19cm; 50 axial slices 2mm thick, b value = 1000.
S2: 64 directions were acquired on a 3T Siemens Trio scanner at Beijing Normal University with the following parameters; TR/TE=7200/104ms, 128x128 matrix, FOV=24cm; 49 axial slices 2.5mm thick, b value = 1000. These data are freely available for download at http://www.nitrc.org/frs/?group_id=383.

ROI selection:
Results from a previously published fMRI study with a mixed gambles task (Tom et al., 2007) were used to define six ROIs that were activated in response to the magnitude of potential gains and losses.

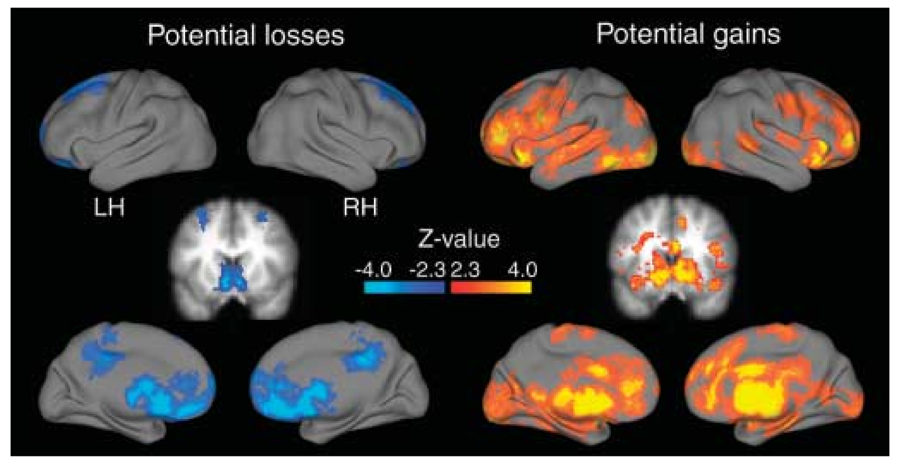

Figure 1: Whole-brain analysis of parametric responses to size of potential loss (left) or gain (right). From Tom et al. 2007.

Another set of 305 ROIs roughly equal in size were derived from the Harvard-Oxford Atlas were used to probe connectivity in a large-scale network of regions spanning the whole brain.

Probabilistic tractography:
These ROIs were used as seeds for probabilistic tractography using FSL's probtrackx with 5000 iterations. Connectivity values from all ROIs for each of eight probabilistic maps per subject were used to create a matrix to probe white matter connectivity of the eight regions to one another. Consistency of results for the 6 ROIs was confirmed by running ten iterations of the analysis using ten resampled random subsets of 28 voxels from each ROI to correct for different ROI sizes between the regions.

Results

Connectivity of the decision making network:

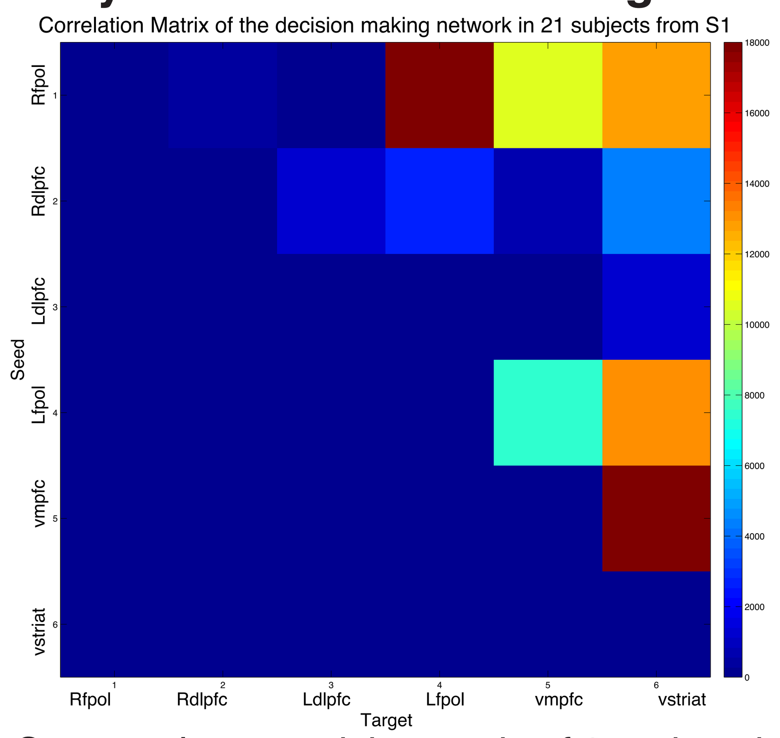

Figure 2: Structural connectivity matrix of 6 regions in the decision making network in two samples.

Connectivity matrices generated using the full seed ROIs and those using the iterative method described above were also significantly correlated within sample 1 ($r=0.49$, $p<0.01$). The pattern of connectivity within this network is thus consistent. Regions most consistently and strongly connected are the vmPFC, ventral striatum, right and left frontal poles.

Connectivity of a large-scale brain network:
Connectivity matrices were generated for the two samples using 305 ROIs spanning the whole brain in the two samples; these matrices were significantly correlated ($r=0.66$, $p<0.001$).

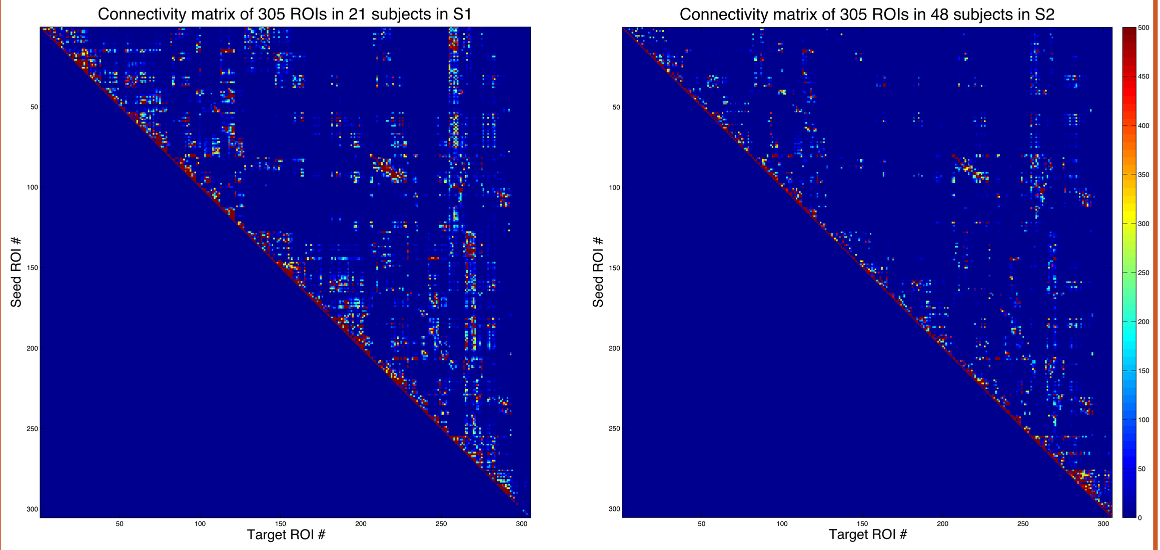

Figure 3: Structural connectivity matrix of 305 regions in a large-scale whole-brain network.

Consistency with functional connectivity:
As can be seen in poster 512.03/YY67, this pattern of structural connectivity is consistent with the pattern of functional connectivity as calculated on task-based fMRI data using a representational similarity analysis (in S1 using the 6 DM ROIs, $r=0.62$, n.s. and using the 305 ROIs $r=0.19$, n.s.) or using a beta-series analysis (in S1 using the 6 DM ROIs, $r=0.44$, n.s. and using the 305 ROIs, $r=0.18$, n.s.).

Conclusions

The pattern of structural connectivity within the decision making network is consistent across samples and is replicable using a resampling technique to account for different ROI sizes.

Characterizing the structural connectivity in the healthy decision making network can help better define differences in the network's pattern of connectivity in disorders such as addiction and will likely help better understand the etiology of impaired decision making.

Structural connectivity in a large-scale network encompassing all brain regions is also consistent across samples and with previous findings.

Structural and functional connectivity as calculated on task-based fMRI data are consistent in these two networks.

A better understanding of the pattern of connectivity and relationship between structural and functional connectivity is key for using noninvasive techniques to probe large-scale systems neuroscience questions in humans.

References

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