Social network analysis of functional connectivity

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Introduction

Functional connectivity analysis based on MRI time series has enabled the study of brain systems without external stimulation[1]. However, most functional connectivity analysis techniques utilize only a fraction of the available information, and the meaningful display of large amounts of data is challenging. This paper describes the use of social network analysis[2] for the characterization of functional networks within the brain.

Materials and Methods

Social network analysis was performed using Matlab on seven MRI time series previously acquired from five rats (TR 100 ms, TE 20 ms, 3600 images, GE-EPI at 11.7T). Images were thresholded to remove non-brain structures. The time course from every voxel was low pass filtered (0.2 Hz cutoff) and cross-correlated with the filtered time course from every other voxel. All pixel pairs that had a correlation coefficient of greater than 0.6 were considered to be 'connected'. Pixels were then sorted into groups, with each pixel belonging to only one group. A pixel was considered to be part of a group if it was 'reachable' from a pixel in that group, i.e. had a correlation coefficient above the threshold with at least one member of the group. The groups were plotted and the average number and size of the groups was recorded. In the largest group, the density of connections and mean number of connections per pixel were also measured. The pixel with the most connections was chosen as the central starting point and networks of other pixels in that group were sorted into tiers based upon how many steps away from the central pixel they were.

Results

Two to thirty two groups were formed in each rat. Most of the groups consisted of a small number of pixels, but one group was generally large, with an average size of 235±220 pixels. This large group contained both primary somatosensory areas (SI) and the motor cortex in 3 rats (Fig. 1), one SI, motor cortex and subcortical structures in 1 rat, and only motor cortex in 1 rat. The average density of this group (ratio of connections to all possible connections) was 3.5%±0.6%. In all of the rats that had a group containing SI, the two most central pixels were located in SI. The average density of connections for these pixels was 40±10%. Three of these rats exhibited distinct groups when tiers were created based upon the distance from the most central pixel. In all three, motor cortex and SI were distinctly separated (Fig.2). In the rat where subcortical structures were included in the large group, they were distinct from both SI and motor cortex based upon tier analysis.

Discussion

The results shown indicate that social network analysis may be useful for analysis and characterization of MR functional connectivity data. The process can be completely automated with no bias caused by user selection of ROIs. Maps are easily interpreted as they show pixels connected at a given correlation level. Results are similar to previous data analyzed with user-defined cross correlation or independent component analysis[3].

The work presented here is in the preliminary stages and will be extended to include more detailed and quantitative analysis. We plan to incorporate measures of centrality as an improvement over tier-based identification of cohesive groups. We are also extending these studies to human experiments. The primary challenge lies in optimizing the algorithms used, as a typical whole-brain human study has 16 times the data of the rat studies used for technique development and our current algorithms are computationally intensive. We also plan to examine the use of this technique for stimulation-based experiments.

References: 1. Biswal, B. et al, *MRM 1995;34:537-41*. 2. Wasserman, S, Faust, K, Social Network Analysis, Cambridge University Press, 1994. 3. Williams, K.A. et al, *Proc ISMRM 2006, 2119.*

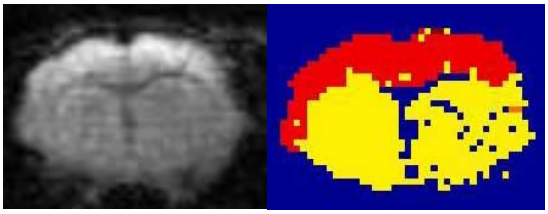

Fig.1. Anatomic image (L) and map of groups (R) for one rat. Brain regions that do not belong to a group are indicated in yellow. Two groups of 2 pixels each (orange and dark red) and one group of 230 pixels (bright red) are present.

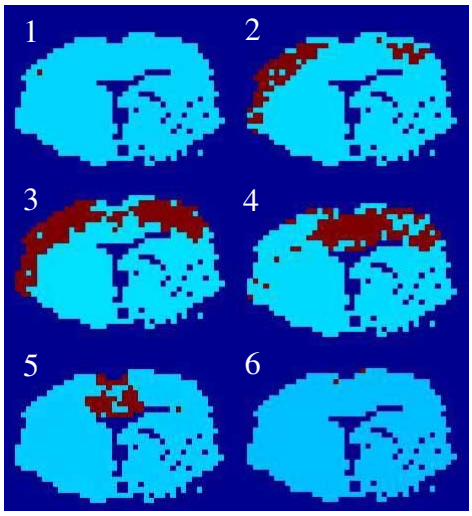

Fig.2. Position of tiers for the largest group shown in Fig. 1. The central pixel (top left) is in SI, and both SIs are primarily contained within the next two tiers, meaning that they are connected to the central pixel directly or via one intermediate pixel. Motor cortex is contained in tiers 4 and 5.