A Toolbox for Human Brain Local Oscillation Analysis

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INTRODUCTION

For both resting-state and task-related functional MRI data, analysis of functional connectivity between all pairs of voxels, i.e. measuring the temporal coherence of the oscillations between them, is key to a clearer understanding of the global mechanisms governing information processing. However, such analyses are computationally extensive rendering them impractical and not readily applicable. To that end, we aimed at developing a more efficient toolbox that could calculate degree as well as other metrics in significantly shorter durations. Meanwhile, we introduced a processing method to apply this toolbox to explore age and gender effects on brain functional connectivity in resting-state fMRI data.

METHODS

- The toolbox has three main functions:
  1. Calculating the slope for the log-linear power spectrum
  2. Determining the temporal coherence across all pairs of voxels in a brain
  3. Calculating global and local efficiency.

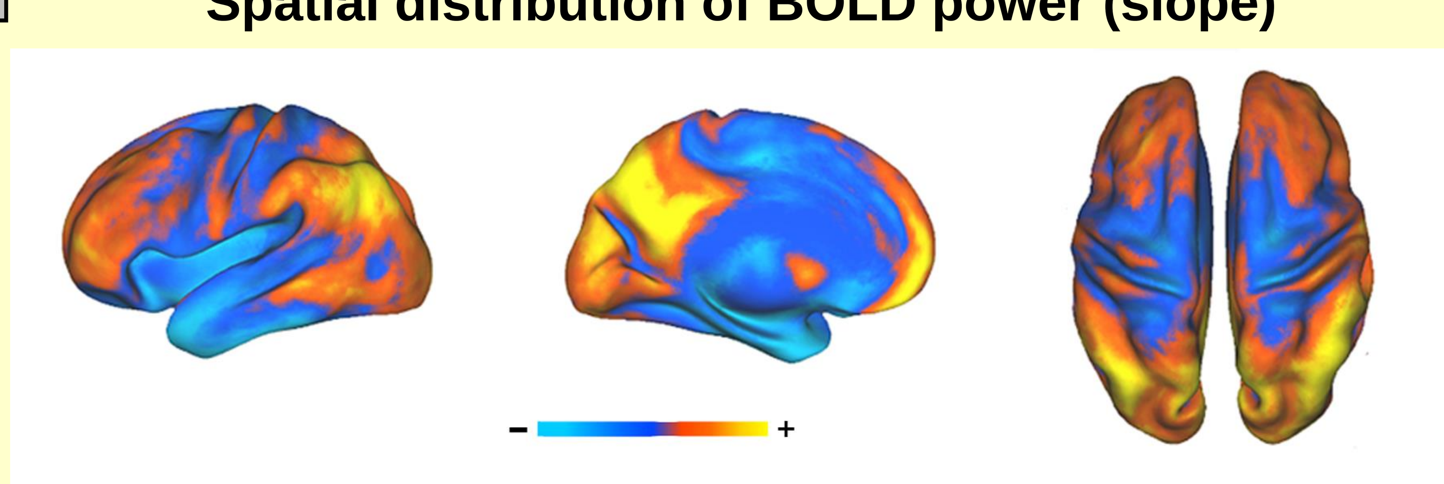
- In function 1, the slope is a metric identified in our lab to simply describe voxel-wise power distribution across the BOLD band width [1]. The larger the absolute value of the slope is, the higher the relative power at lower frequencies in the signal.

- In function 2, three metrics are included:
  1. Degree count of each voxel to other voxels given a predefined correlation threshold (Linkage Density)
  2. Voxel-wise mean correlation with all other voxels (Mean R);
  3. Average anatomical distance from each voxel to all other brain voxels weighed by its degree count.

- In function 3, the global and local efficiency, a rather well-known graph metric, quantifies the effectiveness of information transfer within the brain.

- To use this toolbox to explore the effects of age and gender on functional connectivity, 80 subjects (45 males and 35 females, age = 41.2+/-11.3 years) were recruited to have a 10-minute resting-state scan. All data were collected on a Siemens 3.0 Tesla Trio Tim whole body system with an 8-channel head coil. Acquisition parameters were as follows: voxel size = 3.4375x3.4375x3 mm; in-plane matrix resolution = 64x64; 36 slices; repetition time = 2.5 s; echo time = 30 ms, flip angle = 90° ; number of volumes = 244. The slices covered the whole brain from the cerebellum to the vertex.

1 Spatial distribution of BOLD power (slope)



Hot region represents the higher relative power at lower frequencies

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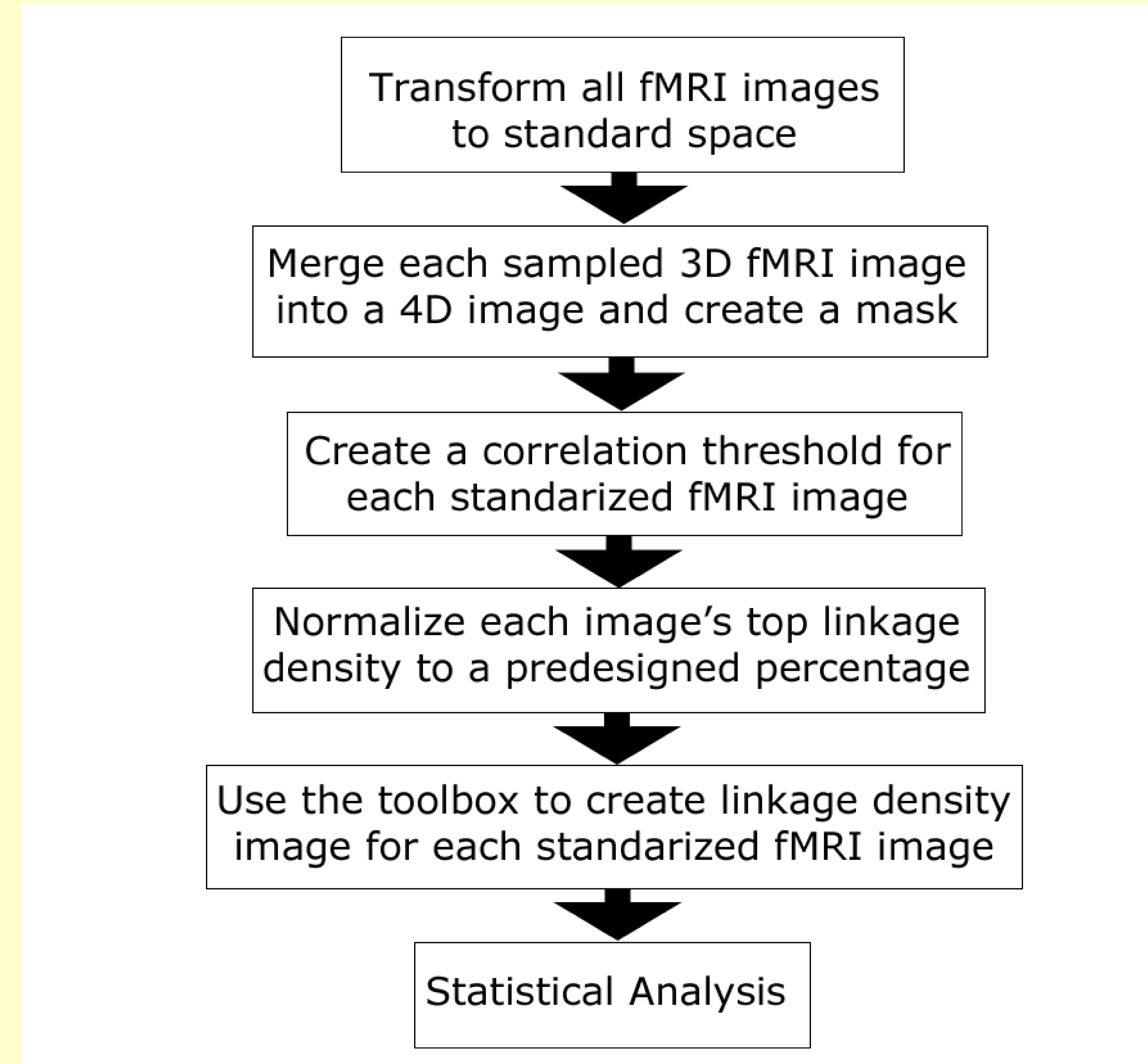
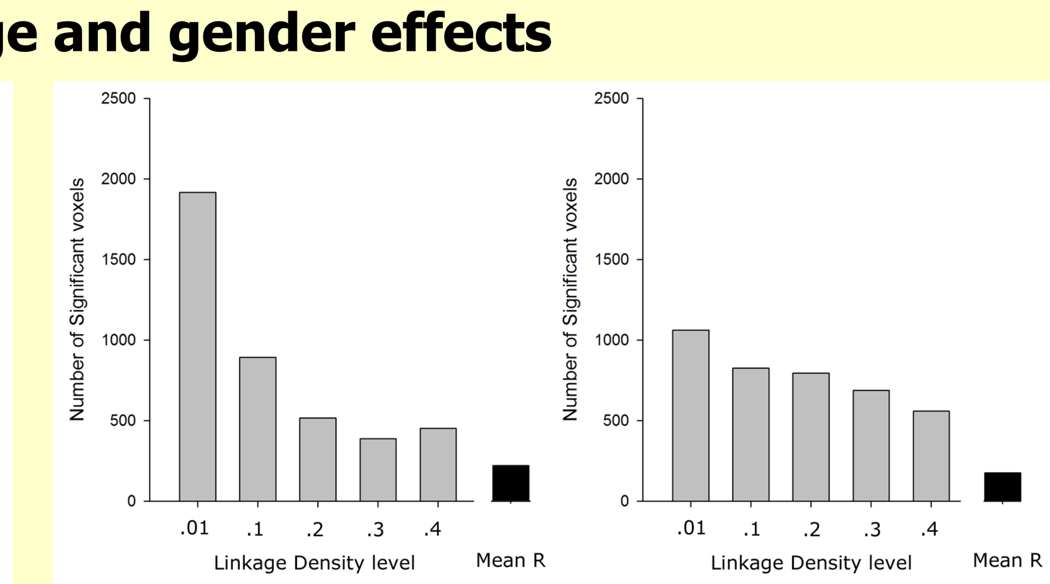
2 Flow diagram of normalized linkage-density analysis

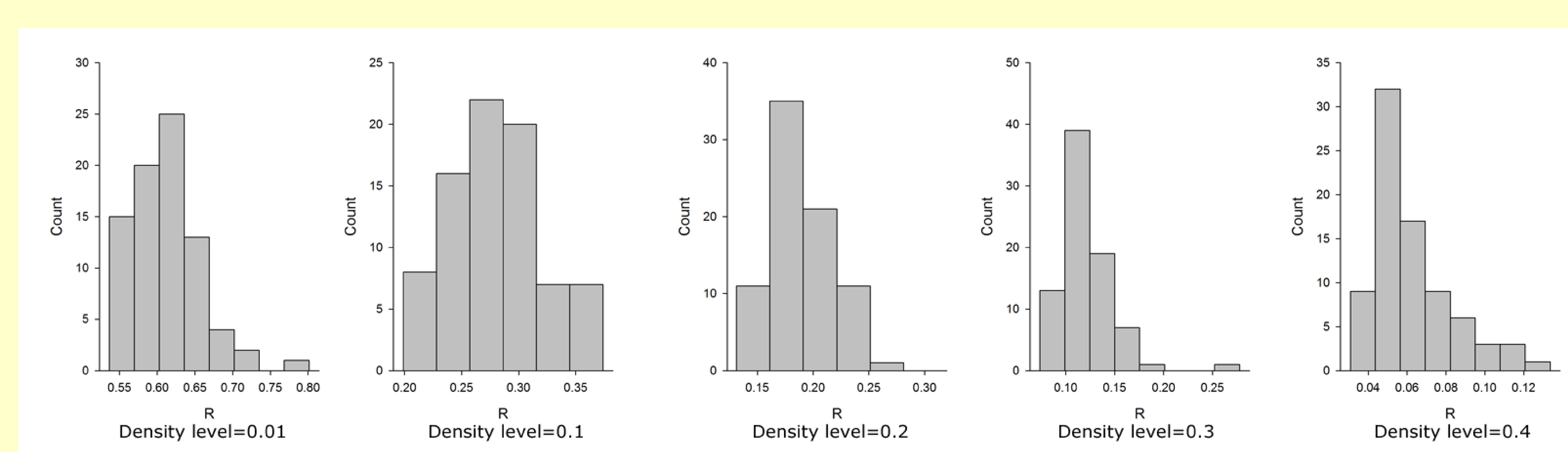


3 Age and gender effects

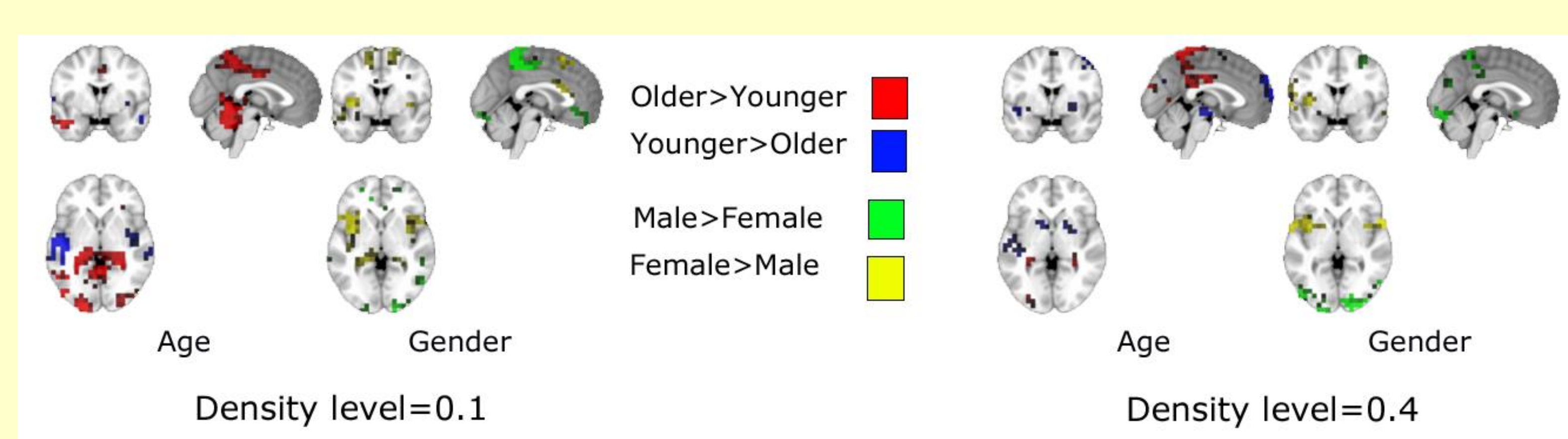
Age and gender of 80 subjects



Number of significant voxels of age (L) and gender (R) effects



Histogram of correlation coefficients



Age and gender effects on functional connectivity of the brain

CONCLUSIONS

- This toolbox is a powerful instrument for human brain local oscillation analysis. Each of the three functions have already been successfully implemented by all members of our lab. The source code is ready to be shared.

- The method of normalized linkage density is better than that of correlation because it contains more significant voxels and matches the property of sparseness of small-world networks in the human brain.