Incorporation of regional homogeneity in seed definition for the resting-state functional MRI analysis

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Introduction

Recently, studies of human brain connectivity using resting-state (RS) functional MRI (fMRI) have attracted increasing attention (1).

Functional connectivity within the default mode network (DMN) has generated significant interests in neuroscience and clinical studies.

Seed-based correlation analysis was used on resting-state data to assess the functional connectivity of DMN, anti-correlation network of DMN (2) and others.

Regional homogeneity (ReHo) method based on calculation of Kendall coefficient of concordance (KCC) was developed to measure the temporal similarity of a given voxel with its nearest neighbors in the RS-fMRI data (3).

Purpose of this study

To propose a method for improving the sensitivity of the conventional seed-based correlation analysis (SCAC) by incorporating the ReHo information (SCAReHo) in the seed selection.

To analyze DMN connectivity in patients with stenosis of the internal carotid artery (ICA), before and after stenting, and compare the results of SCAC and SCAReHo.

Methods

Subjects data and Data acquisition

Group One:

Twelve young healthy volunteers
- 6 females; age: 23 to 28 years

RS-fMRI experiments:
- 3 Tesla GE HDx scanner
- T2*w single-shot gradient-echo EPI sequence
  - TR/TE/FA = 2000 ms/ 30 ms/ 90°
  - in-plane matrix = 64 x 64
  - slice thickness = 3 mm with 1 mm gap
  - 28 continuous axial slices per volume
  - 325 volumes

Discarding the first 10 volumes: 180 volumes

During the RS-fMRI scan:
(1) Subjects lay supine in the scanner with their head fixed
(2) Be instructed to keep their eyes closed, to remain awake, to think of nothing, and to perform no specific task during the scan

Data processing

- Motion Correction
- Spatial Normalization to the MNI template
- Spatial smoothing (8-mm Gaussian kernel)
- Removal of linear trend
- Temporal band-pass filtering (0.01–0.1 Hz)
- Regress out nuisance covariates
  - Global
  - White matter
  - CSF
- Motion components

Preprocessed data REST

Functional connectivity

SPM2

Preprocessed Data

Time course of whole brain voxels

EPI Data

Functional connectivity

PCC mask (6)

Regional Homogeneity

KCC mask (KCC > 0.5)

Combination

PCC seeds (2,4,5)

PCC seeds (2,4,5)

Reference time course

Average z scores

Cluster sizes

Table 1

<table>
<thead>
<tr>
<th></th>
<th>SCAC</th>
<th>SCAReHo</th>
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</thead>
<tbody>
<tr>
<td>MPFC</td>
<td>0.631 ± 0.080</td>
<td>0.635 ± 0.077*</td>
</tr>
<tr>
<td>L_IPC</td>
<td>0.676 ± 0.097</td>
<td>0.621 ± 0.096*</td>
</tr>
<tr>
<td>R_IPC</td>
<td>0.646 ± 0.112</td>
<td>0.704 ± 0.128*</td>
</tr>
</tbody>
</table>

*: p < 0.05; **: p < 0.01

Average z scores

Cluster sizes

Group Two:

Twenty-seven patients with unilateral ICA stenosis
- 6 females; age: 66 ± 7.84 y

Two scans: before and six months after stenting

RS-fMRI experiments:
- 3 Tesla Siemens MRI scanner
- TR/TE/FA = 2000 ms/50 ms/90°
- in-plane matrix = 64 x 64
- slice thickness = 5 mm without gap
- 20 continuous axial slices per volume
- 150 volumes

RS-fMRI data (3).

To analyze DMN connectivity in patients with stenosis of the internal carotid artery (ICA), before and after stenting, and compare the results of SCAC and SCAReHo.

Seed selection for SCAReHo

- PCC seeds (2, 4, 5)
- MPFC seeds (6)

Results

Figure 1 shows the group results of the DMN connectivity obtained by the SCAC and SCAReHo methods for each seed ROI within PCC and a PCC mask combined with the KCC mask, respectively.

Figure 2 shows paired t-test results of the DMN connectivity compared between SCAC with SCAReHo.

Quantitative analyses demonstrated significantly stronger connectivity with greater spatial extents (p<0.05) with SCAReHo as comparing to SCAC:

Average z-score: MPFC with seed3, L_IPC with seeds 2 and 3, and R_IPC with seed3

Cluster size: MPFC with seed3, L_IPC with seed3, and R_IPC with seeds 1 and 3

Average z scores

Table 2

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Cluster sizes

Table 3

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<tbody>
<tr>
<td>MPFC</td>
<td>116.8 ± 66.8</td>
<td>103.3 ± 74.7</td>
</tr>
<tr>
<td>L_IPC</td>
<td>75.8 ± 44.3</td>
<td>51.4 ± 43.0</td>
</tr>
<tr>
<td>R_IPC</td>
<td>29.0 ± 22.2*</td>
<td>47.3 ± 30.0</td>
</tr>
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*: p < 0.05; **: p < 0.01; ***: p < 0.005

Group Two:

Figure 3 shows the group results of the DMN connectivity obtained by the SCAReHo method.

With the SCAC analysis (not shown), only few or no voxels in the seed and the DMN regions were detected in most patients. The SCAReHo method significantly improved the detection in all patients.

Improvement of functional connectivity was found after the treatment with the SCAReHo analysis.

Conclusion

This study proposed a novel method of RS-fMRI network analysis by incorporating ReHo in the seed definition.

SCAReHo analysis improved the detection of FC in DMN using the RS-fMRI, thus may be particular helpful when subjects exhibit distinct functional anatomy compared with normal populations.

References