Poster 1642

Correlation and Spatial Coherence of Functional Homogeneity, Cortical Curvature and Thickness

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Introduction

Resting-state fMRI is a prominent tool for analyzing brain function. The effects of development, aging and diseases on the local brain organization can be assessed by quantifying the local coherence of the rs-fMRI signal [5]. However, the relationship between this functional property and structural determinants such as cortical thickness and cortical curvature has not been investigated in depth, most of the studies focusing on the correction of motion/registration artifacts [1].

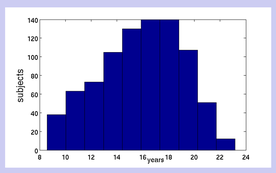
In this work, a population of 859 subjects imaged as part of the Philadelphia Neurodevelopmental Cohort [2] was used for measuring the local functional homogeneity of the cortex (FH) and its correlation with local cortical thickness (CT) and curvature (CC). The significance of the spatial correlation of these maps was estimated by randomly realigning them in a similar fashion as [8], however, we improved the prior approach by using spherical harmonics for boosting the computations. Whereas CC was not correlated with any FH measure, we found the correlation between cortical thickness and the functional homogeneity measures to be moderate and consistent. This relationship should be carefully considered in studies of FH.

Methods

The structural and functional scans of a large (neurodevelopmental) cohort were registered using Freesurfer. Structural and functional measures were computed for each subject and averaged across the population. The correlation and the alignment of all the maps obtained were computed as explained below.

Data

- 859 scans/subjects acquired as part of the Philadelphia Neurodevelopmental Cohort [2]
- for fMRI, motion correction was performed through confound regression [4] and the time series were band-pass filtered [3]
- projection onto Freesurfer fsaverage5 surface (10 242 nodes per hemisphere)
- structural measures provided by Freesurfer



Distribution of the subjects considered for this study, according to their age.

rs-fMRI Functional Homogeneity measures (FH)

For each node j and four different neighborhoods (of geodesic radii 1 to 4), three different measures of Functional Homogeneity (FH) were defined (v_j being the BOLD signal at j):

- **average Pearson correlation (APC)** : $APC = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \langle v_i, v_j \rangle$
- **Kendalls Coefficient of Concordance** (KCC) is a nonparametric measure of agreement between ranked data

$$KCC = \frac{12}{N^2 T(T^2-1)} \sum_{t=1}^{T} \left(R_t - \overline{R}\right)^2$$

$$R_t = \sum_{j=1}^{N} r_{t,j} \qquad \text{and} \qquad \overline{R} = \frac{1}{2} N(T+1)$$

where $r_{j,t}$ is the rank obtained for v_j^t, the value measured at time t at the location j. In the context of fMRI, this measure is refered as **regional homogeneity** (reHo) [5]

- **joint mutual information** of the v_i, provided by Kraskov estimator [6]:

$$I(\{v_j\}) = \Psi(k) + (N-1)\Psi(T) - \frac{1}{T} \sum_{t=1}^{T} \sum_{j=1}^{N} \Psi(n_j(t))$$

where k denotes the number of nearest-neighbors considered (3 in this work), $n_j(t)$ counts nearest neighbors of v_j^t and Ψ is the digamma function: $\Psi(x) = \Gamma(x)^{-1} \frac{d\Gamma}{dx}$

Statistical tests of alignment

- **alignment** defined as the p-value associated with the correlation between two cortical maps projected on the sphere, when the two maps are randomly rotated w.r.t. each other.
- the computational burden was reduced by representing the maps with **spherical hamonics**
- the spherical harmonics are rotated efficiently using **Wigner matrices** [7]
- the rotation were represented in the Euler convention and sampled uniformly

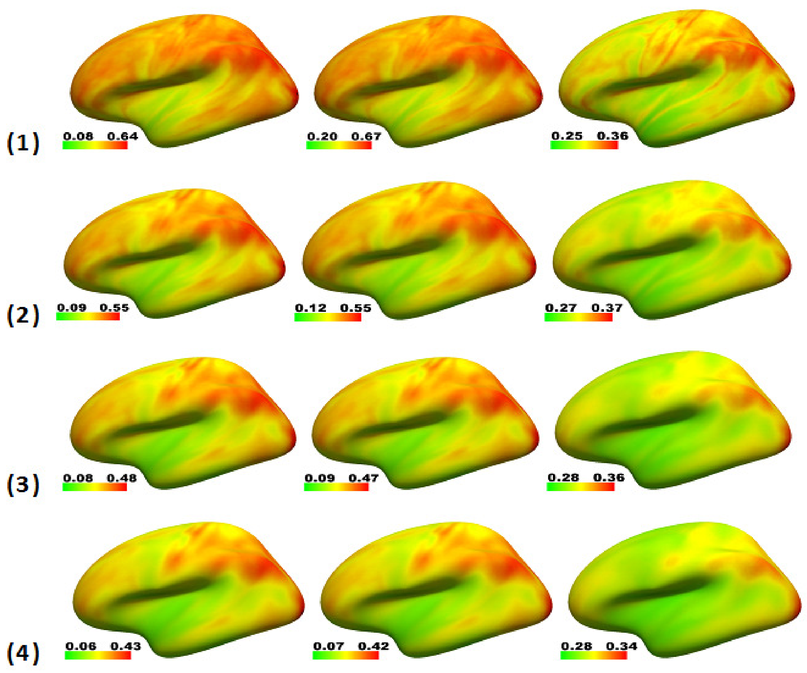


Fig. 1 Regional homogeneity measured for the temporal surface of the left hemisphere. First column: average correlations; second column: reHo; last column: mutual information. The rows correspond to the radius of the neighborhood chosen for computing the measures.

	FH measures						CC	CT
FH	1.00	0.87	0.99	0.96	0.88	0.94	0.00	-0.35
	0.87	1.00	0.83	0.80	0.85	0.78	-0.07	-0.32
	0.99	0.83	1.00	0.99	0.91	0.98	-0.01	-0.35
	0.96	0.80	0.99	1.00	0.91	1.00	-0.03	-0.36
	0.88	0.85	0.91	0.91	1.00	0.91	-0.11	-0.35
	0.94	0.78	0.98	1.00	0.91	1.00	-0.04	-0.37
CC	0.00	-0.07	-0.01	-0.03	-0.11	-0.04	1.00	-0.44
CT	**-0.35**	**-0.32**	**-0.35**	**-0.36**	**-0.35**	**-0.37**	-0.44	1.00

Fig. 2 Pearson correlation between the FH measures, the cortical curvature (CC) and the cortical thickness (CT). The FH measures are not correlated with the cortical curvature. On the contrary, moderate and very significant correlations (close to -0.35, p-value$< 10^{-100}$) are observed between the FH measures and the cortical thickness.

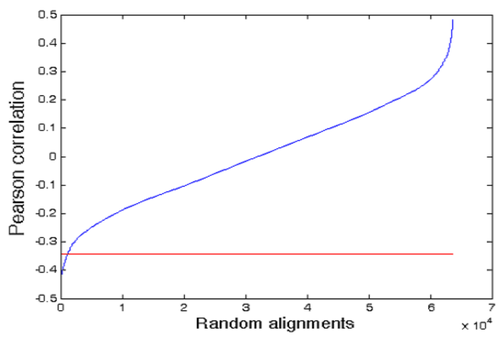


Fig 4. Pearson correlation between the first FH measure and the cortical thickness (CT) (in red) and Pearson correlations simulated by 10^5 random realignment (in blue). **Associated p-value: 1.8%.** The p-values associated with the alignments of the 12 FH maps with the CT map are respectively: [1.8% 1.7% 1.2% 1.8% 1.7% 1.4% 1.6% 1.5% 1.3% 1.3% 1.4% 1.3%]

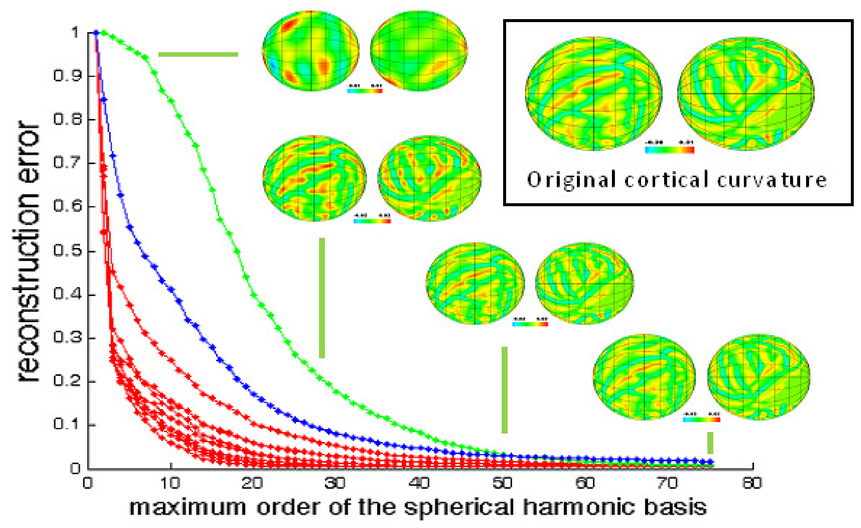


Fig 3. Reconstruction error, measured by the sum of square differences between the original cortical map and the map reconstructed from the projection onto the spherical harmonic basis, for increasing basis order, for the 12 FH cortical maps (in red), the cortical thickness (in blue) and the cortical curvature (in green).

Results

- Functional homogeneity maps are very correlated, in particular at large scale
- Average correlation maps and KCC/ **reHo** maps are almost identical
- Most of the cortical maps are well reconstructed with a basis of degree 30 (900 coefficients)
- **Cortical Thickness** is quite anti-correlated with FH measures, and these maps are **very well aligned**

Conclusion

In a cohort of 859 individuals of age 8-23, we measured the correlation and the alignment of 12 measures of functional homogeneity w.r.t. the curvature and the thickness of the cortex. All the functional homogeneity measures were highly correlated. No relationship was observed between local functional homogeneity and cortical curvature. By contrast, the cortical thickness is moderately and significantly anti-correlated with all the homogeneity measures. We found also that these maps are well aligned. **We suggest therefore to systematically account for the cortical thickness when analyzing functional homogeneity measures** .

In the future, we will investigate the local relationships between cortical thickness and regional homogeneity, in order to further elucidate the underlying mechanisms, we will study the effect of neurodevelopment and compare the FH patterns with the patterns of long-range connectivity.

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