Poster 1641

Penn

Subject-specific Parcellations Detect Reduced Local Functional Coherence during Neuro Development

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Introduction

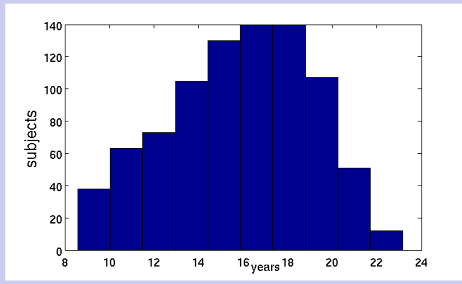
Resting-state functional MRI is a prominent tool for studying brain organization, but high-resolution connectivity analyses are intractable. The spatial dimension of the data can be automatically reduced by defining ROIs where the signal is averaged [5,6]. This approach can extract reproducible population-level parcellation when individual data are concatenated. However, functional anatomy is known to vary across subjects, hence using a common group parcellation is not optimal. On the other hand, individual data is noisy and subject level parcellation would introduce correspondence issues for group-level analysis.

In this work, we extend the parcellation method GraSP [1] for warping population level parcels to subjects data and we show how informative properties can be derived in this manner, in particular for elucidating the effects of neuro development on local brain organization. We used data from 859 subjects imaged as part of the Philadelphia Neurodevelopmental Cohort [2].

Methods

Data

- 859 scans/subjects acquired as part of the Philadelphia Neurodevelopmental Cohort [2]
- motion correction was performed through confound regression [4]
- time series were band-pass filtered (0.01 – 0.08 Hz)
- projected onto Freesurfer fsaverage5 surface (10 242 nodes per hemisphere)



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

Correlations shrinkage

shrinkage of the individual correlation matrices Σ_s toward the population mean:

$$\Sigma_p = \frac{1}{859} \sum_{s=1}^{859} \Sigma_s$$

by a same, large amount λ:

$$\overline{\Sigma_s} = (1-\lambda)\Sigma_s + \lambda \Sigma_p$$

During our experiments, λ was set to a large value, 0.85, in order to remove most of the individual scan noise, but far from 1 for preserving subject-specific BOLD signal.

Parcellation

- parcellation of the population with GraSP [1]
  → **population parcellation**
- parcellation of each subject independently, so that:
  - correlation are replaced by the shrinked correlations $\overline{\Sigma_s}$
  - subject-specific parcellations have the exact same parcels center as the population
  - outlier removal (nodes weakly connected with all the parcel centers are assigned to a virtual parcel)

→ **comparable subject-specific parcellations flexibly adapted to individual data**

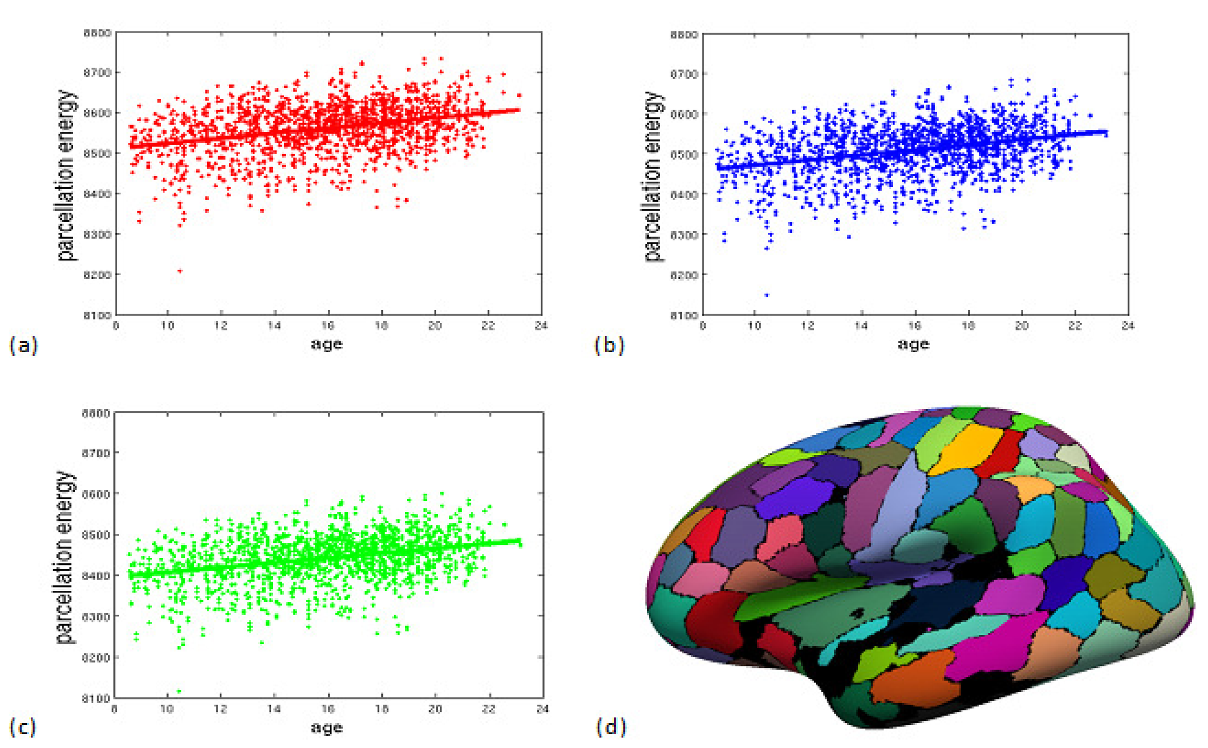


Fig 1. Individual parcellation energy w.r.t. age, for (a) population-level parcels (b) subject-specific parcels (c) subject-specific parcels without outliers. The energy significantly decreases between these three plots (paired t-test p-values < 10^{-100}). For each plot, a significant increase of energy with age is observed (p-values: (a)1.3 10^{-43} (b)1.2 10^{-44} (c)4.9 10^{-43}) (d) one subject specific parcellation without outliers (they correspond to large black areas).

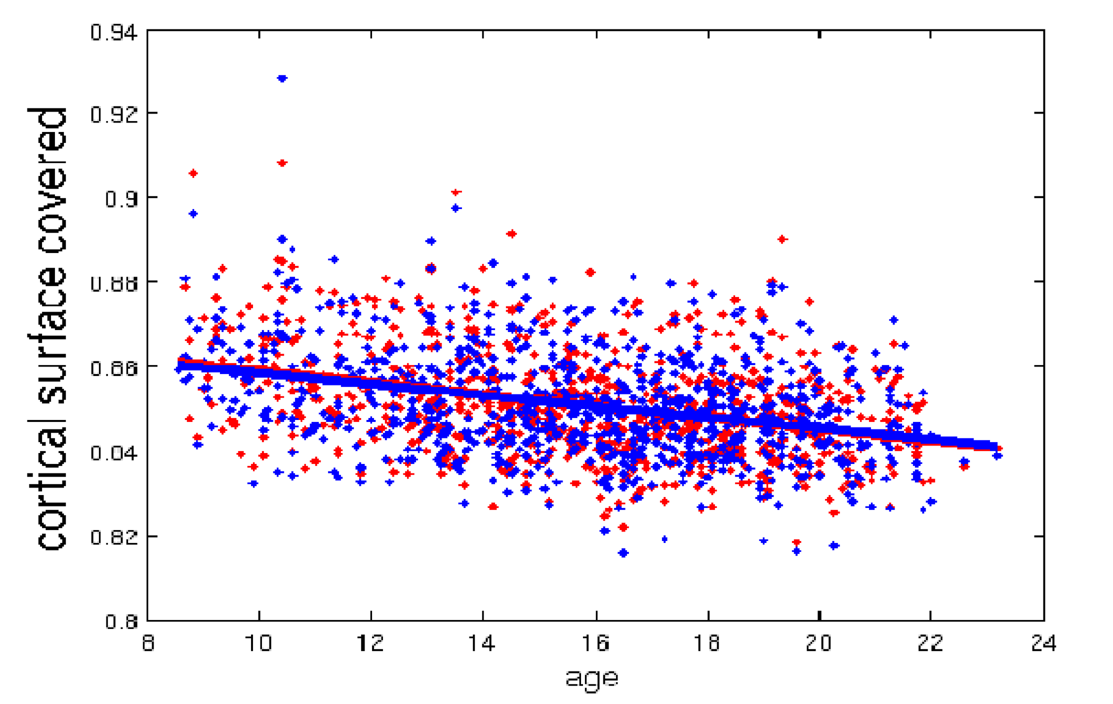


Fig 2. Fraction of the cortical surface covered by the parcellations, for both hemispheres (red: left hemisphere ; blue: right hemisphere). The p-value associated with the linear regression for the left (resp. right) hemisphere is 1.2 10^-28 (resp. 8.1 10^-24)

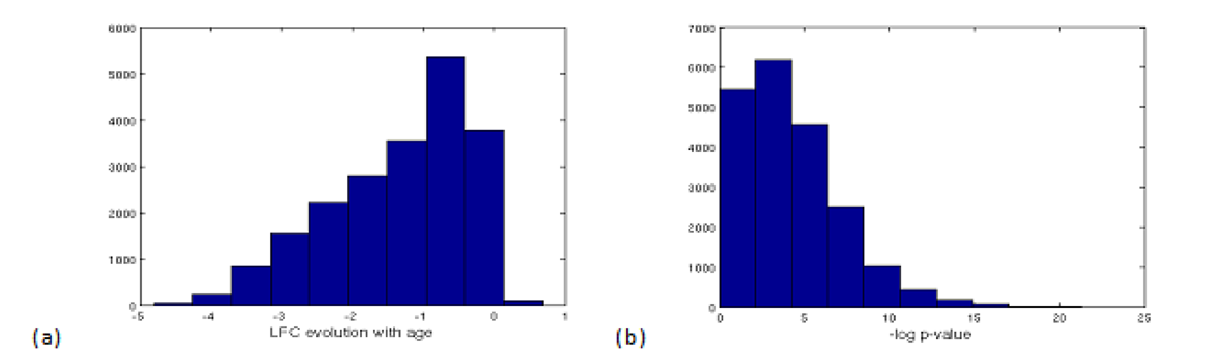


Fig 3. (a) effects of age on LFC, measured using linear regression while co-varying for sex, race and motion ; reported for the 20484 cortical nodes (b) associated p-values. For most of the nodes, LFC drops. These evolutions are often very significant (p-value < 10^{-4})

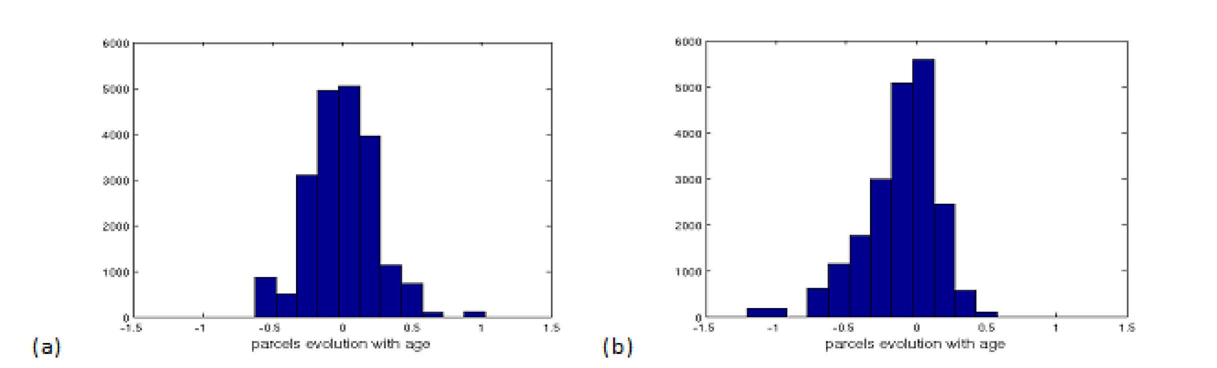


Fig 4. Effects of age on parcel area, measured using linear regression while co-varying for sex, race and motion; reported for the 20484 cortical nodes for (a) subject-specific parcellations covering the cortex and (b) subject-specific parcellations without outliers. When outliers are removed, many more parcels can shrink simultaneously and the distribution (b) is, compared to (a), shifted towards negative values.

Results

Our findings are threefold. (1) The fit of the parcellation to the data improves when the parcels are warped to the individual data and when outliers are removed (2) A significant reduction of functional coherence with age was consistently observed for the whole cortex (3) when outliers are removed, this evolution can be captured by the area of the parcels as well.

Improved fit with subject specific parcellation

The fit of the parcellation to the subject data (measured by the parcellation energy) improves as expected:

- when subject-specific parcellations are derived from the population level parcellation (Fig 1.b versus Fig 1.a)
- when the algorithm is allowed to remove outliers (Fig 1.c versus Fig 1.b).

The proportion of outliers discarded in this experiments is shown in Fig 2. The neurodevelopmental trend revealed when the population-level parcellation is used for analyzing the individual data **was not altered** by the subject-specific parcellations and outliers removal.

Neurodevelopment

All the settings reveal the same trend: the parcellation energy increases with age, which indicates that **local functional coherence diminishes with age**. We confirmed this phenomenon twice, by showing

- that when outliers are removed, it induces a **small but very significant reduction of the cortical coverage of the parcellation** with age, shon in Fig 2.
- that the area of the geodesic disks computed by GraSP (LFC), that are based on Pearson distance, shrinks with age (sometimes very significantly Fig 3.)

Parcel sizes and neurodevelopment

According to Fig. 4:

- when the parcellation covers the whole brain, some parcels compensate the evolution of the others. The evolutions are small and not significant.
- when outliers are removed, parcels are free to shrink simultanously. Larger evolutions are observed. Some of them are slightly significant.

No single parcel was shown to evolve as significantly as parcellation energy, that was **the most reliable age correlate.**

Conclusion

In this paper, we presented a novel method for the warping of population parcellation to subjects' data and we have derived informative properties from these parcellations. We have demonstrated with a database of 859 scans that (1) the novel parcellations better fit the data and (2) they can be used for capturing strong neuro developmental effects. In particular, we have consistently captured a decrease of local functional coherence with age that could be interpreted as an increase of functional segregation during neuro development.

Future Work

In the future, we will examine whether features describing the subject parcel shapes provide additional information with respect to parcel connectivity, and we will demonstrate that nodes defined using subject-specific parcels improve analyses of network connectivity, in particular for disease diagnosis/prognosis purpose

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Acknowledgements

This work was partially funded by NIH grant R01AG14971 and supported by RC2 grants from the NIMH MH089983 and MH089924, as well as T32 grant MH019112. TDS was supported by K23 grantMH098130 and the Marc Rapport Family Investigator grant through the Brain and Behavior Research Foundation.

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