Decoding Age-specific Changes in Brain Functional Connectivity Using a Sliding-window Based Clustering Method

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Abstract

Understanding the typical development of functional neural circuits may help us generate hypotheses regarding developmental psychopathologies. In this work, we aim to identify more nuanced age-period-specific functional connectivity (FC) development patterns. We proposed a sliding-window based clustering approach to identify a more refined age interval of development for the functional network. We used resting-state fMRI (rs-fMRI) data from the human connectome project-development (HCP-D), which recruited children, adolescents, and young adults ranging in age from 5 to 21 years. Our analysis revealed significant sex effects on the development patterns, which were consistent over measures. We extracted the FC network corresponding to each development pattern and summarized it from 3 aspects: global network statistics, modular connectivity, and development-related hubs. Several unique developmental hub structures and age-specific patterns were discovered.

Introduction

Investigating the functional neural circuits in normal development can

- Identify when development abnormalities arise
- Determine where, when, and how to intervene and thereby prevent illness persistence.
- Help generate hypotheses regarding the neural bases of developmental psychopathologies
- Help to improve diagnosis and treatment

Maturation of functional connectivity (FC) can be examined by quantifying age-related changes in the strength and spatial distribution of intrinsic brain networks

Problems:

- The developmental evolution of FC is not following a linear trend over the adolescent period,
- The onset and the duration of the changes may vary from regions to regions

Aim: identify various age-period-specific FC developing patterns

- Describe the nonlinearity
- Cluster FCs by their developing curves

Methods

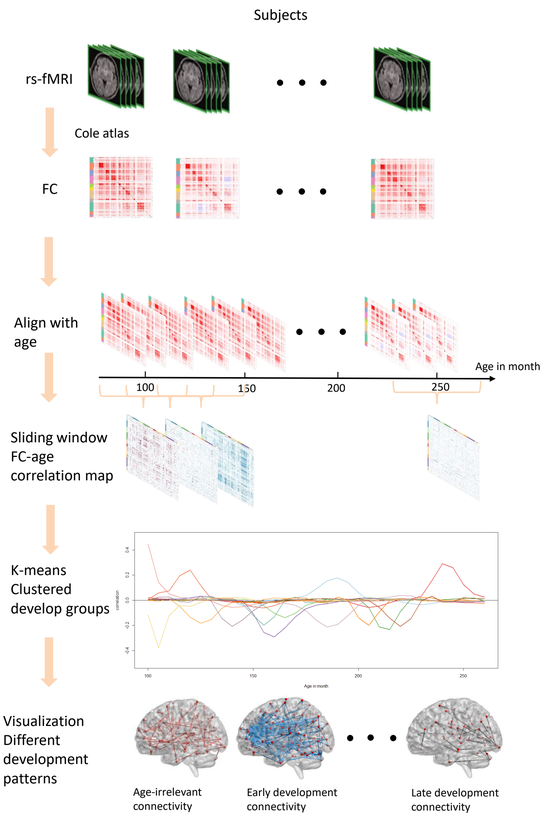


Fig 1: The flowchart of detecting age-specific development patterns.

Materials

- Participants:
- From the human connectome project-development (HCP-D) [1]
- Healthy children, adolescents, and young adults
- Exclude participants with excessive head motion during scanning
- N = 528

Table I: Demographic information

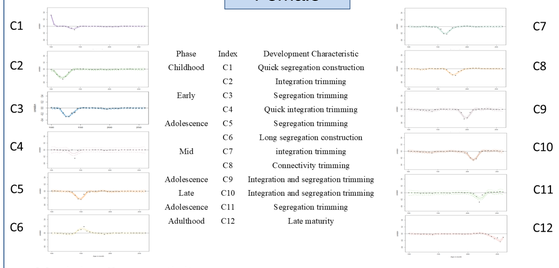
	F (N=290)	M (N=238)	Total (N=528)
Age in month			
Mean	177.452	181.437	179.248
Min	76.000	67.000	67.000
Q1, Q3	140.250, 217.750	146.000, 221.000	144.000, 218.250
Max	263.000	263.000	263.000

- Image acquisition and pre-processing
- Resting-state fMRI
- 3T Siemens Prisma platform
  - TR/TE= 800/37 ms, flip = 52, FOV= 208×180 mm, matrix = 104×90, slices = 72
  - Duration: age>8, 26 min; age<8, 21 min
- HCP minimal preprocessing pipelines [2]
- Cole parcellation [3]

Results

Identified development curves and characteristics

Female



- Modular Connectivity

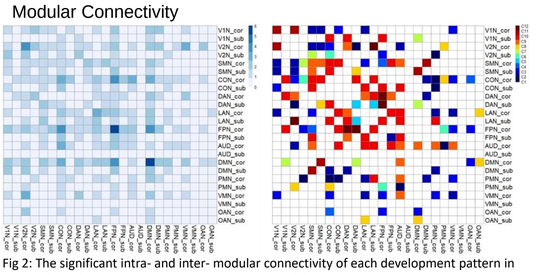
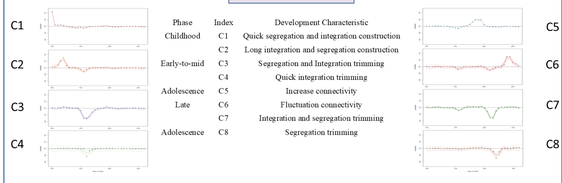


Fig 2: The significant intra- and inter- modular connectivity of each development pattern in female. Left: The frequency of the modular connectivity's over all patterns, where the colors represent the frequencies; Right: Pattern-specific connectivity's, where the colors represent different development patterns.

Male



- Modular Connectivity

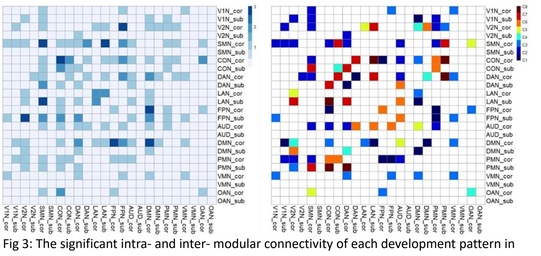


Fig 3: The significant intra- and inter- modular connectivity of each development pattern in male.

Conclusions

- Childhood-to-adolescence is a unique period of development, with major changes occurring across the brain at many different levels of brain functioning.
- Females matured earlier than males in functional development , but males had higher development rate.
- The CON, FPN and DMN actively developed in both males and females.
- Cerebellum has appeared as a hub area in development for both genders, but at different age ranges.

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