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Precision Functional Mapping of the Adolescent Brain Using Multi-Echo Resting-State fMRI

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INTRODUCTION

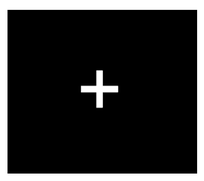
- Precision Functional Mapping (PFM)[1,2] enables the detection of **individualized functional brain networks**.
- PFM has shown that adults display stable features of brain network topography that deviate from group averages.[1,2]
- Association networks such as the default (DN) and frontoparietal (FPN) networks can be decomposed into parallel sub-networks hypothesized to support dissociable functional roles.[2,3,4]
- However, limited developmental research has adopted this approach,[4,5,6] and it remains unknown whether adolescents exhibit this adult-like segregation of DN and FPN.
- Research Questions:
  1. **Is PFM a feasible approach to investigate the topography of the adolescent brain?**
  2. **Do adolescents exhibit idiosyncratic organization of association networks?**

METHODS

Data Acquisition:

Eight adolescents ages 13-16 (4 F)

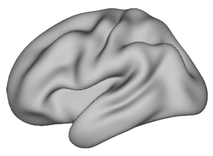
Eight MRI sessions on a 3T Siemens Prisma scanner



- 18-24 minutes of a fixation task collected per session
- 186.1±4.7 minutes of resting-state multi-echo (ME) fMRI data collected from each participant across all sessions

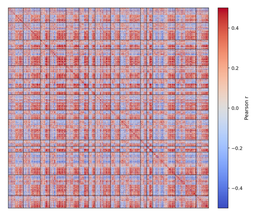
MRI Sequences:
TR = 1355 ms; Voxel Size = 2.4 mm
TE = 12.80 ms, 32.39 ms, 51.98 ms, 71.57 ms, and 91.16 ms

Preprocessing & Analysis:

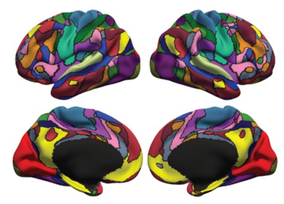


Preprocessing with iProc[2] pipeline adapted for ME data[7] → minimizes interpolations to preserve individual anatomical details

- Motion correction
- Optimal echo combination with tSNR weighting
- Nuisance regression
- Bandpass filtering (0.01-0.10Hz)
- Spatial smoothing (2mm FWHM)
- Projection to surface space



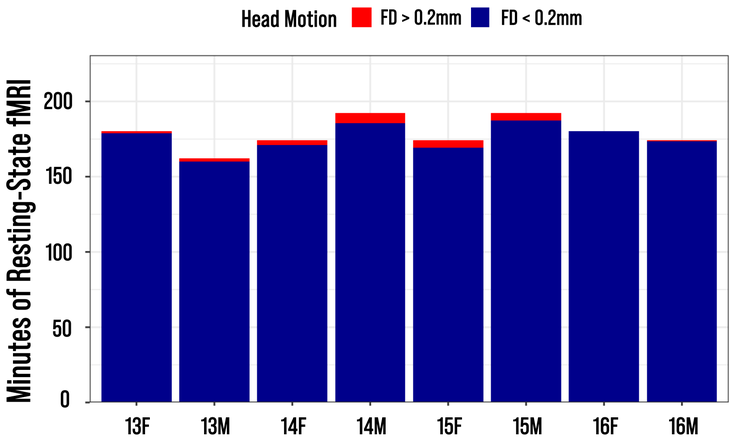
- Compute functional connectivity (FC) matrices
- Assess within-person reliability curves and split-half reliability



Multi-Session Hierarchical Bayesian Modeling (MS-HBM)[8] to define individualized networks (k=15)[9]

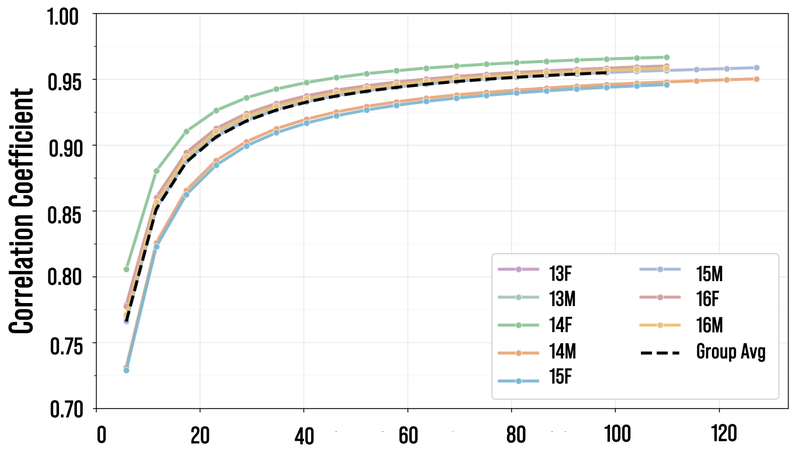
RESULTS

Approximately Three Hours of Resting-State fMRI Data Retained Per Participant



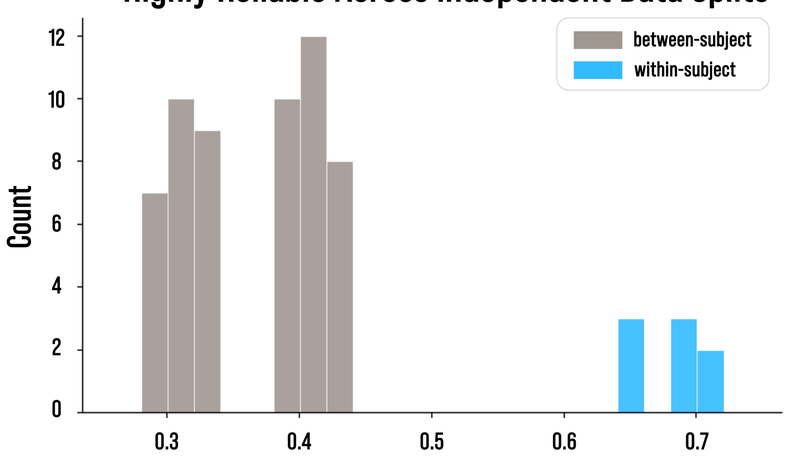
- Data quality was assessed with a motion threshold of framewise displacement (FD) < 0.2 mm.
- Participants retained 98% of all data collected, yielding an average of **175 minutes of low-motion resting-state fMRI data per participant.**

Twenty-Five Minutes of Multi-Echo Resting-State Data Needed for High Reliability



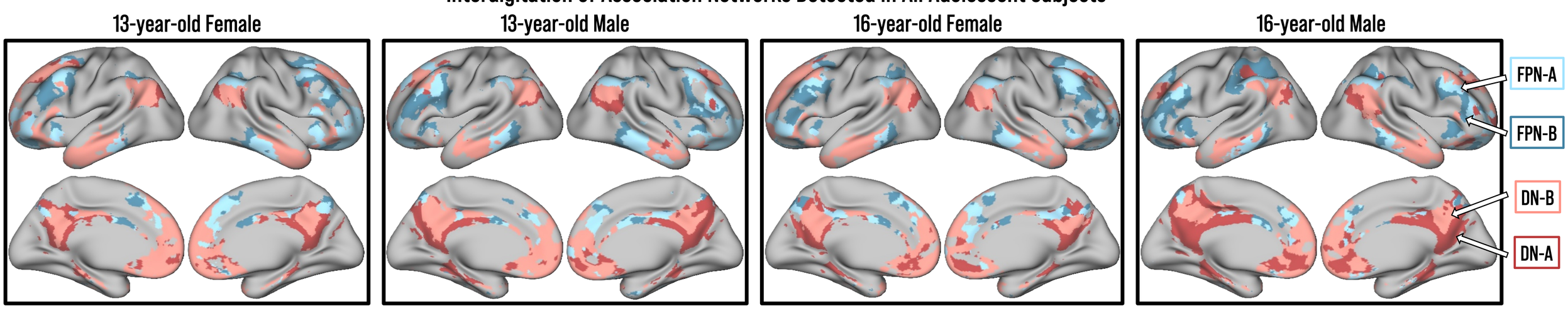
- Within-person reliability curves were assessed by correlating a fixed 60-minute "true" FC matrix with incrementally accumulated independent test data.
- **25 minutes** of ME resting-state data yielded a correlation of 0.9 with the "true" FC matrix.[10]

Within-Subject Functional Network Parcellations Highly Reliable Across Independent Data Splits



- Individualized network parcellations were highly reliable across independent data splits.[6]
- This suggests that parcellations capture **stable, individual-specific network organization** rather than shared group-level topology.

Interdigitation of Association Networks Detected in All Adolescent Subjects



DN-A: Default Network A
DN-B: Default Network B
FPN-A: Frontoparietal Network A
FPN-B: Frontoparietal Network B

- Individualized parcellations of large-scale functional brain networks revealed idiosyncratic features of the DN and FPN across participants.
- Further, the DN and FPN can be decomposed into 2 parallel, interdigitated sub-networks in all participants (including the remaining 4 participants not displayed).

DISCUSSION

- Our findings reveal that PFM can be leveraged in adolescents to yield high-quality resting-state fMRI data and reliable FC estimates, allowing us to characterize individualized parcellations of association networks in adolescents.
- These data suggest that traditional approaches using group averaging may be obscuring individual differences in functional network topography during adolescence, a period of life when association networks continue to refine.
- Future analyses will employ seed-based analyses and investigate task-based activation patterns in adolescents using individualized parcellations.

REFERENCES

1) Gordon et al., 2017. *Neuron.* **2)** Braga & Bucker, 2017. *Neuron.* **3)** DiNicola et al. 2020. *J. Neurophysiology.* **4)** He et al. 2026 *bioRxiv.* **5)** Flournoy et al. 2024. *NeuroImage.* **6)** Demeter et al. 2025. *bioRxiv.* **7)** Edmonds et al. 2024. *Science Advances.* **8)** Kong et al. 2019. *Cerebral cortex.* **9)** Du et al. 2024. *J. Neurophysiology.* **10)** Lynch et al. 2020. *Cell reports.*

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