Precision Estimation Reveals that Adolescents Exhibit Idiosyncratic Organization of Functional Brain Networks

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INTRODUCTION

- The **frontoparietal network (FPN)** supports cognitive control, allowing individuals to flexibly adapt behavior.[1]
- The FPN follows a **protracted developmental trajectory** that extends into late adolescence and early adulthood.[2]
- However, studies of FPN development typically use group-averaging, which may obscure fine-grained features of individuals' idiosyncratic functional networks.
- Studies using **Precision Functional Mapping (PFM)**[3] in adults found that the FPN fractionates into two parallel, interdigitated sub-networks – FPN-A and FPN-B[4] – which may support distinct behaviors.
- Although cognitive control continues to develop during adolescence[5], **it remains unknown whether adolescents exhibit fractionation of the FPN, or whether this subdivision emerges with age.**

Alternative Hypotheses:

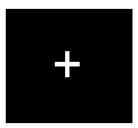
1. Adolescents' FPNs do not yet fractionate due to the protracted developmental trajectory of the association cortex.
2. Adolescents' FPNs do fractionate into two subnetworks, but this distinction was previously blurred by group-averaging approaches.

METHODS

Scan Camp Data Acquisition:

N = 8 adolescents ages 13-16 (4 F)

8 MRI sessions in 4-6 weeks

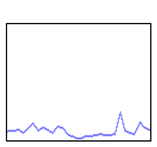


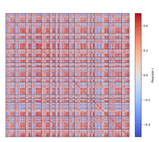
- 18-24 min of a fixation task collected per session
- **186.1±4.7 min** of resting-state multi-echo (ME) fMRI data collected from each participant across all sessions
  - TR=1355ms; Voxel Size=2.4mm; TE=12.80ms, 32.39ms, 51.98ms, 71.57ms, 91.16ms

Preprocessing & Analysis:

- Preprocessing with iProc[6] pipeline adapted for ME data[7] optimized for within-individual alignment of data across sessions
- Includes motion correction, optimal echo combination, nuisance regression, bandpass filtering, spatial smoothing (2mm FWHM), and projection to surface space[8]

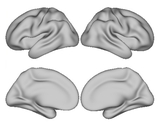
- Assessed motion quality of collected resting-state data on the first echo of each run
- Runs were excluded if absolute displacement (AD) > 5.0mm and truncated if AD > 3.0mm in the second half of the run
- All volumes with framewise displacement (FD) > 0.2mm[3] were censored for all analyses





- Computed vertex-wise functional connectivity (FC) matrices using Pearson's correlation
- Assessed within-person reliability curves to quantify the amount of data needed for high reliability ($r > 0.9$)[3]

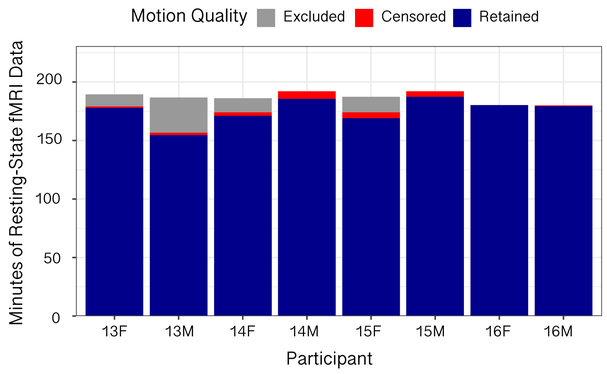
- Applied a Multi-Session Hierarchical Bayesian Model (MS-HBM)[9] using an independent third of the data to estimate individualized networks in each participant with a 15-network[10] solution



- Conducted a complementary seed region-based connectivity analysis[4,10] to confirm MS-HBM network estimates reflected underlying FC patterns

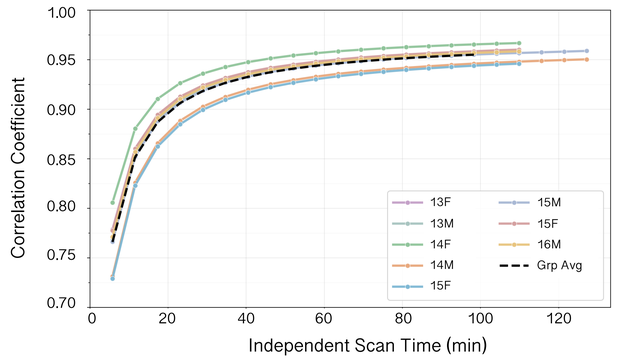
RESULTS

3 Hours of High-Quality Resting-State Data Per Participant



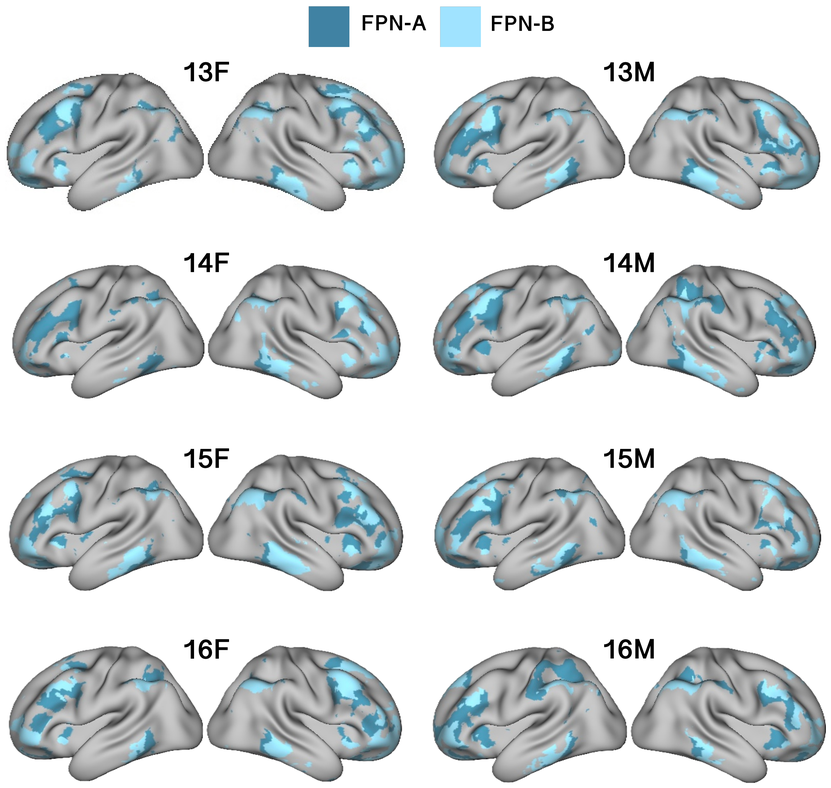
- Data quality was assessed with thresholds of AD > 5mm (Excluded) and FD > 0.2 mm[3] (Censored).
- Participants retained 83-100% of all data collected, yielding an average of approximately **175 minutes of low-motion resting-state fMRI data per participant.**

25 Minutes of Multi-Echo Resting-State Data Achieves High Reliability



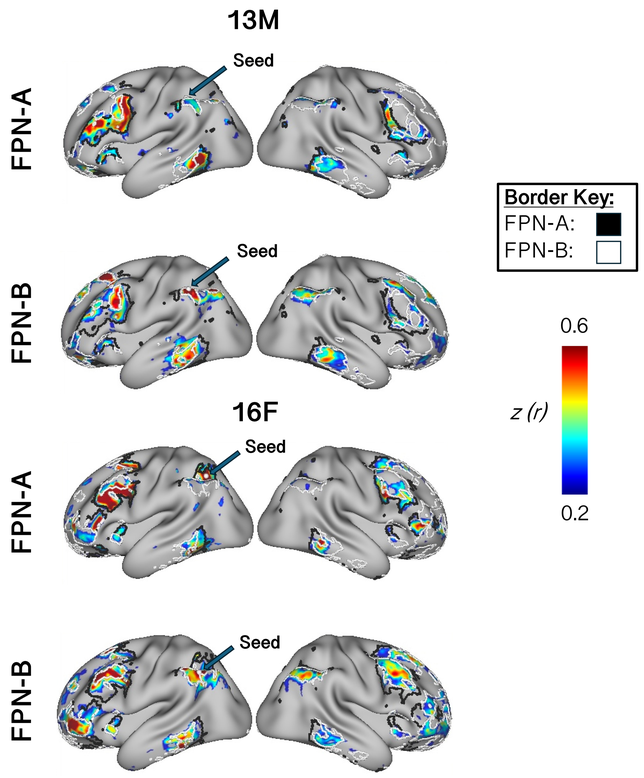
- Within-person reliability curves were assessed by correlating a fixed 60-minute "true" whole-brain FC matrix with incrementally accumulated independent test data.
- **25 minutes** of ME resting-state data yielded a correlation of 0.9 with the "true" whole-brain FC matrix.[11]

FPN Fractionates into Parallel Subnetworks FPN-A and FPN-B



- MS-HBM network estimation identified **two FPN networks** (labeled FPN-A and FPN-B) comprising brain regions within the lateral frontal, posterior parietal, and lateral temporal cortices in all 8 adolescent participants. FPN-A and FPN-B were adjacent to each other.

Seed-Based Connectivity Recapitulates Fractionation of FPN-A and FPN-B



- Seed-based FC patterns correspond to FPN-A and FPN-B network boundaries.
- Lateral prefrontal cortex, posterior parietal cortex, and lateral temporal cortex exhibited **dissociable FC patterns between FPN-A and FPN-B.**

DISCUSSION

- Precision functional mapping is **feasible and reliable** in adolescents, yielding high-quality individualized network estimates.
- The FPN **fractionates into two parallel, interdigitated subnetworks**, FPN-A and FPN-B, in all adolescent participants, consistent with our second hypothesis.
- This organization was detectable at the individual level and **may be obscured by group-averaging** approaches.
- Future analyses will investigate the functional specialization of FPN subnetworks.
- We plan to examine age-related changes in FPN organization in a longitudinal sample of participants who returned 9-12 months later.

1. Vincent et al., 2008. *J .of Neurophysiology.* **2.** Sydnor et al., 2021. *Neuron.* **3.** Gordon et al., 2017. *Neuron.* **4.** Braga & Buckner, 2017. *Neuron.* **5.** Luna et al., 2004. *Child development.* **6.** Braga et al., 2019. *J. of Neurophysiology.* **7.** Edmonds et al., 2024. *Science Advances.* **8.** Fischl et al., 1999. *NeuroImage.* **9.** Kong et al., 2019. *Cerebral Cortex.* **10.** Du et al., 2024. *J. of Neurophysiology.* **11.** Lynch et al., 2020. *Cell reports.*

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