Using Frontera to analyze developmental brain data

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Two things to ponder:

1. People can flexibly configure the specific processes necessary to perform many different tasks

2. This is done on a massively parallel, interconnected architecture in the brain
Just the visual system

Felleman & Van Essen 1991
Executive Function Development
Task Control Development

Mental Well-being

HELLO
I AM...
IN CONTROL
Academic Skill Development

Task Control Development
Our primary lab tool: functional MRI

**Advantages**
- Great spatial resolution (<3 mm!)
- 3-dimensional
- Whole brain
- No radiation

**Disadvantages**
- $$$
- Complicated
- Slow
- One person at a time
- Motion sensitive
fMRI is timeseries data!

Each location (voxel – usually 2X2X2 mm) in the brain has a time series that consists of the T2 signal at each timepoint (usually every 1-2 seconds) across the recording period (5-10 minutes)
Though children are small, their brain data are mighty!
Two things to ponder:

1. People can flexibly configure the specific processes necessary to perform many different tasks

2. This is done on a massively parallel, interconnected architecture in the brain
The bigger idea of functional networks

The Brain is a series of Systems that interact/combine to accomplish our goals

e.g., Gordon et al., 2016
Categories of Hubs
What is a “cortical hub”?

Participation Coefficient

Graph of network organization of brain areas in healthy young adults

Figure from BRAPH.org

Figure: Wig, 2017
Are there clear cortical hub categories in youth and are any associated with executive function task performance?

Resting-state cortical hubs in youth organize into four categories

Demeter, D.V., Gordon, E.M., Nugiel, T., Garza, AC., Larguinho, T., Church, J.A. 2023; Cell Reports, 42 (5)
Participants: ABCD (n=500) and UT (n=67)

50% female
Age range 8.5-17.2 years (mean = 10.3 years)
Mean “clean” scan length (0.25mm FD) = 13:52

Demeter et al. 2023
Functional correlations of the brain at rest
Resting state functional connectivity (rs-fcMRI)

$r = 0.814$

$r = 0.814$

630 s
Youth Hub Identification

• Create 333x333 connectivity matrix

• Community detection per person

• Calculate participation coefficient (PC) for all parcels per person

• Hubs = PC top 20% per person
  • 67 hubs per person

Demeter et al. 2023
Clustering youth hub profiles

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</table>

Connectivity profile for each hub

Use Louvain algorithm to identify clusters of connectivity profiles
Relating any hub profiles to executive function abilities

CogFlex (UT)

Task rule cued (color)

Rules
Response choices
Target

Match target to response based on rule

Card Sort (ABCD)

Demeter et al. 2023
Are there hub categories in youth, and are any associated with executive function task performance?
Demeter et al. 2023
Youth control-processing hubs relate to Cognitive Flexibility

Demeter et al. 2023
3 Different types of cortical hubs relate to task control in adults

Gordon et al. 2018
Developmental trajectories of cortical hubs appear non-linear

* $p < .01$ Bonferroni corrected

Marek et al., 2015
Conclusions

Cortical hub profiles in youths are similar to what have been reported in adults.

But, youth control-processing hubs are split between sensory networks.

These control-processing hubs relate to cognitive flexibility performance in youths.

Understanding cortical hubs helps us understand brain function, communication, and vulnerabilities to injury over development.

Demeter et al. 2023
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Developmental Cognitive Neuroscience Lab
meet the team
Thanks!

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TACC

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