What can light show us about brain activity?: Examining early neural and behavioral predictors of childhood ADHD

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ADHD Diagnostic Criteria (DSM 5)

Listed as a Neurodevelopmental Disorder

Six or more symptoms of Inattention and/or Hyperactivity/Impulsivity

- Symptoms persist for at least 6 months
- Symptoms are present prior to age 12
- Symptoms are present in two or more settings
- Symptoms are not better explained by another mental disorder

Severity of Symptoms and Impairment

Executive Function Skills

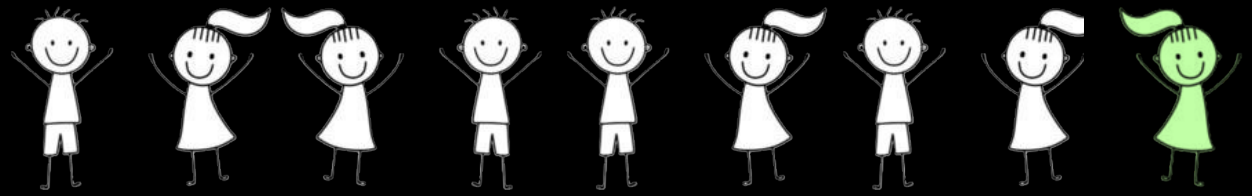
A set of cognitive processes necessary for goal executions

Impulse Control	Working memory	Attention	Problem solving (Planning & organizing)
Responds without considering options	Difficulty keeping track of time	Distractible*	Difficulty forgoing current pleasure for future rewards
Easily excited, impatient, frustrated	Difficulty keeping track of belongings	Difficulty 'multi-tasking'	Impulsive actions (without regard for consequences)
Restlessness & hyperactivity	Difficulty following conversations for appropriate interactions	Fails to finish activities	Difficulty organizing tasks and activities

* Does well with novel or stimulating activities ("hyperfocus")

Many children and adults are affected by ADHD

~1 in 9 children in the U.S.



ADHD persist into adulthood for 2 out of 3 children with ADHD

Individuals with ADHD often experience challenges in many aspects of life

What Causes ADHD?

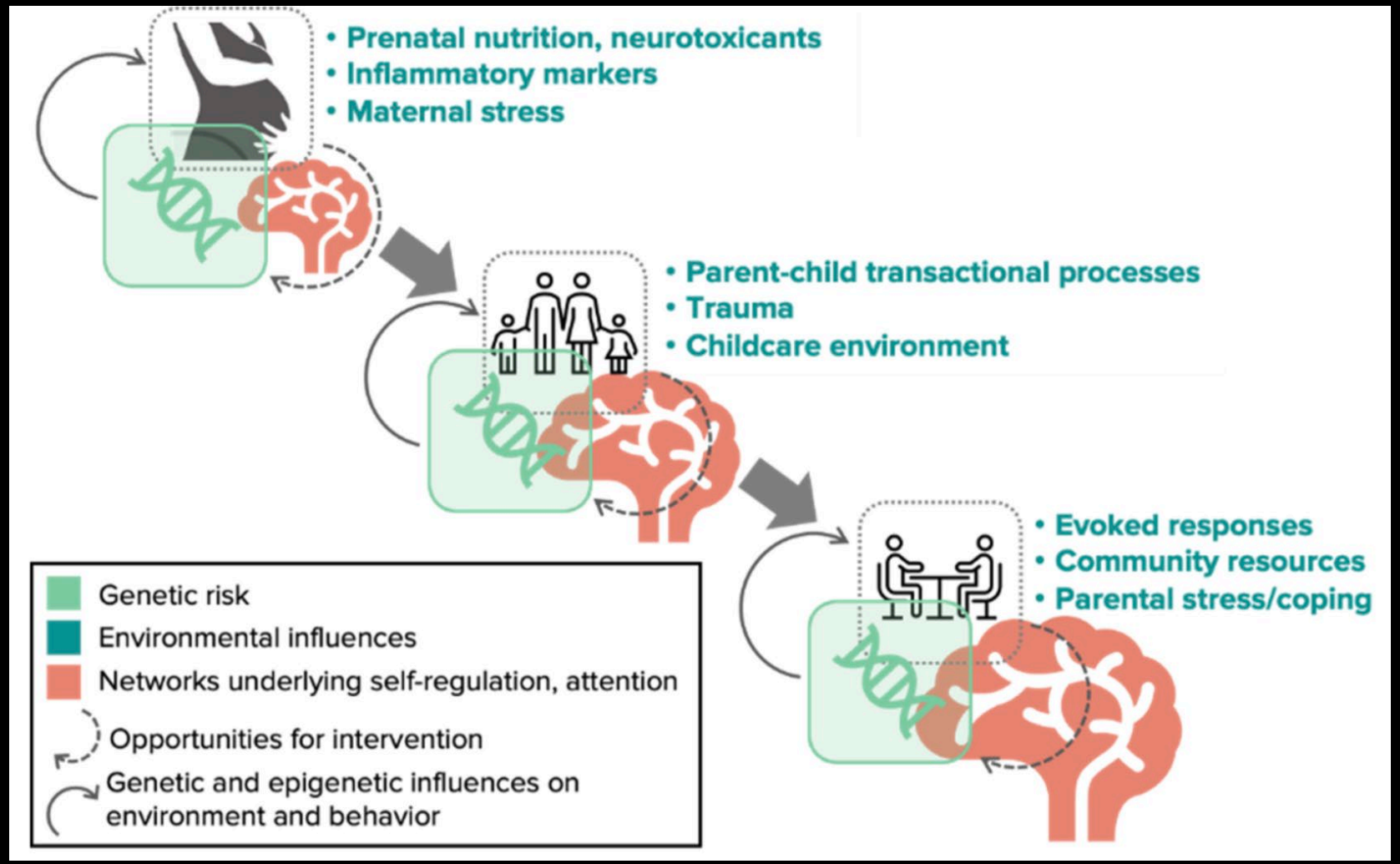


Figure adapted from
Miller et al., 2023 *JCPP Advances*

Featured on the ICIS Baby Blog

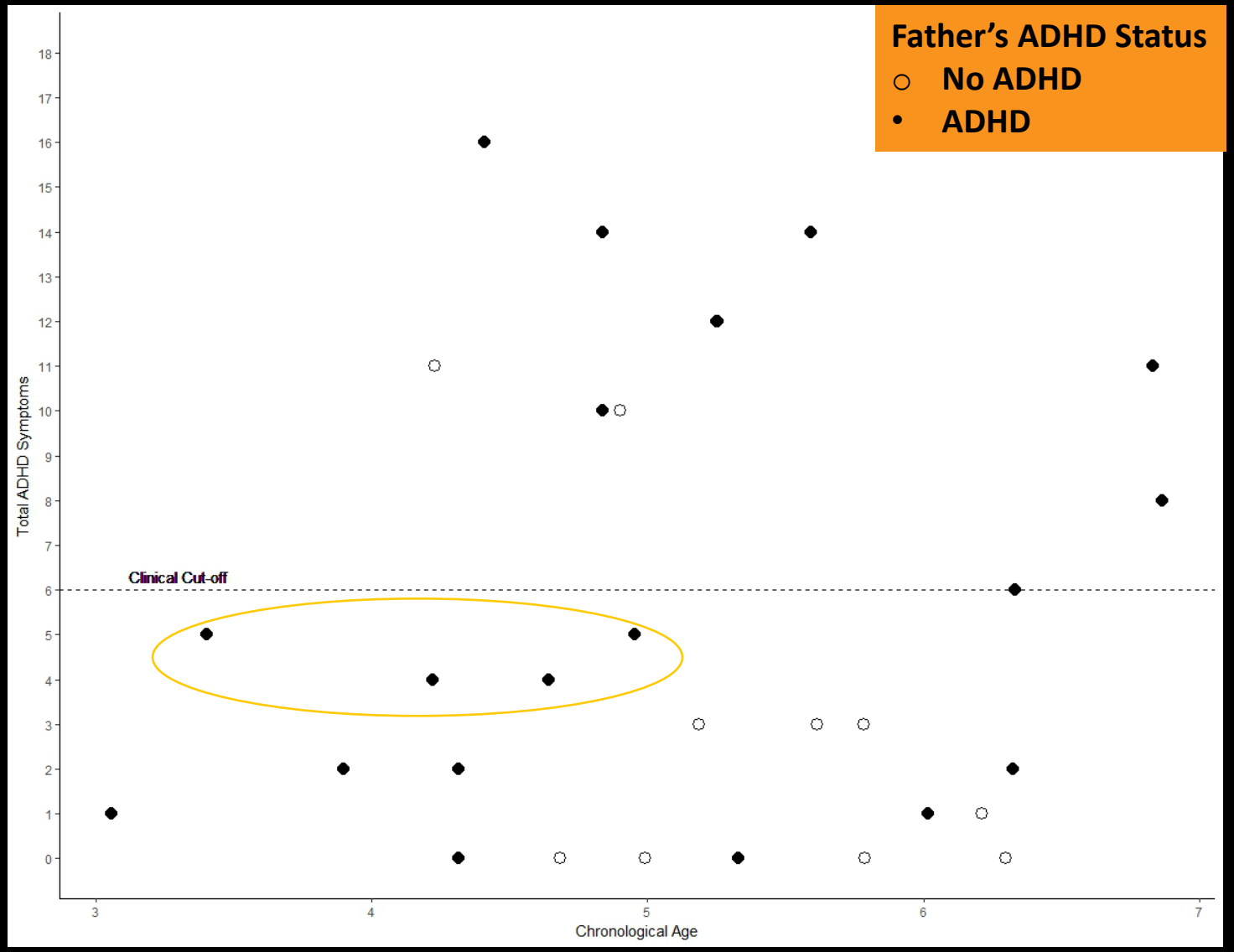
Why Study ADHD?

ADHD is a common reason to present for psychiatric care in childhood

Children are often referred for treatment between 7-9 years of age due to challenges occurring at school and home

Pittsburgh ADHD Longitudinal Study (PALS) Offspring Pilot Study

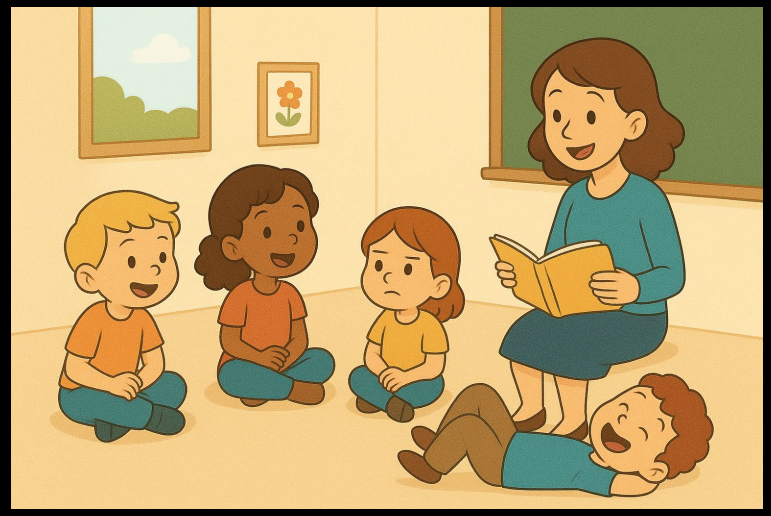
- Examined ADHD symptoms and behavior of 29 young children born to fathers with and without h/o ADHD
- **2.76 Odds of ADHD if father has ADHD**
- 4 Preschool aged children (3-5yrs) were subthreshold for disorder



Joseph et al., 2019 Journal of Child Psychiatry and Human Development

Funding provided by AACAP Pilot Award for Attention Disorders

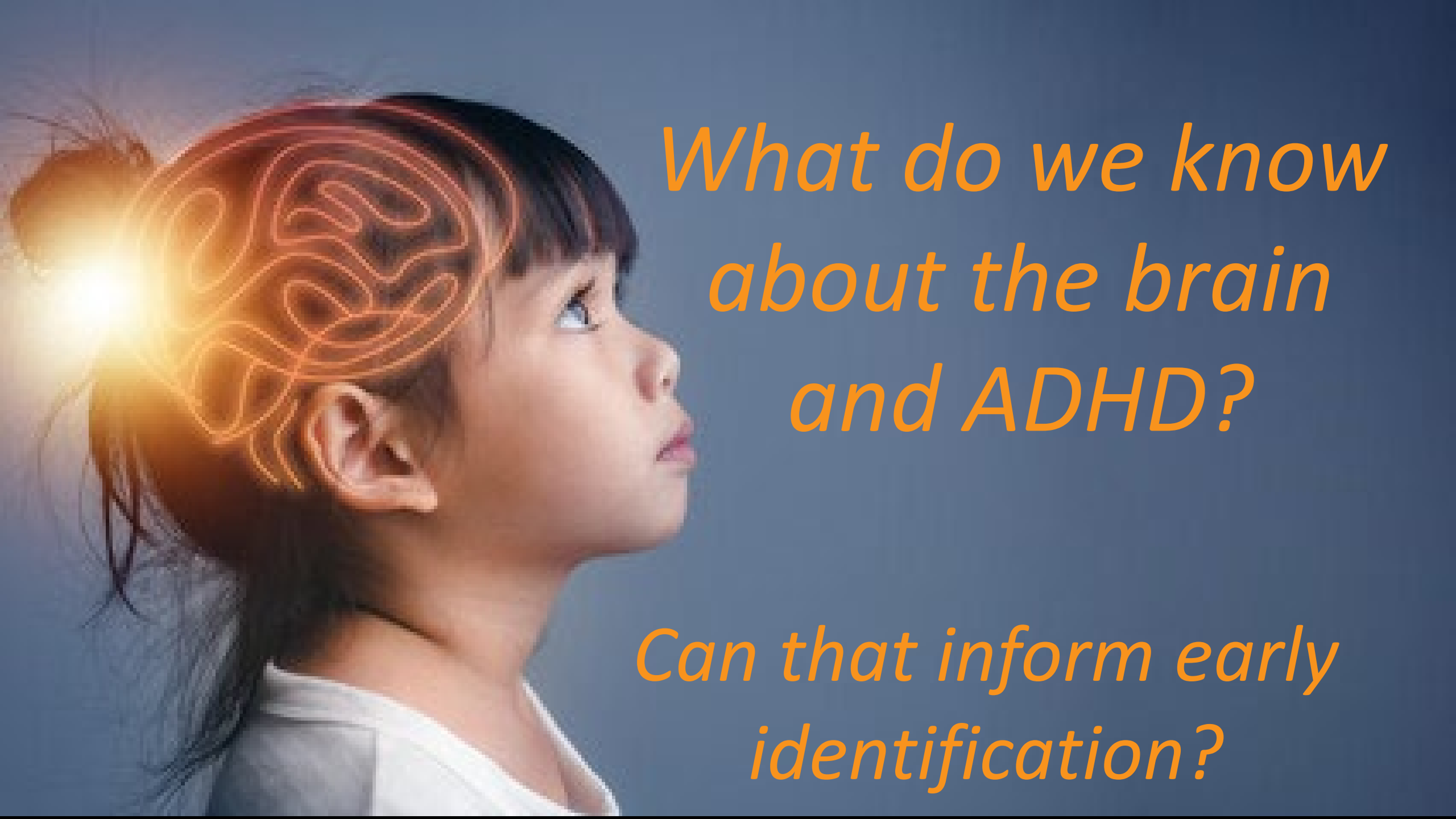
Inattention, hyperactivity, and impulsivity are common among preschoolers



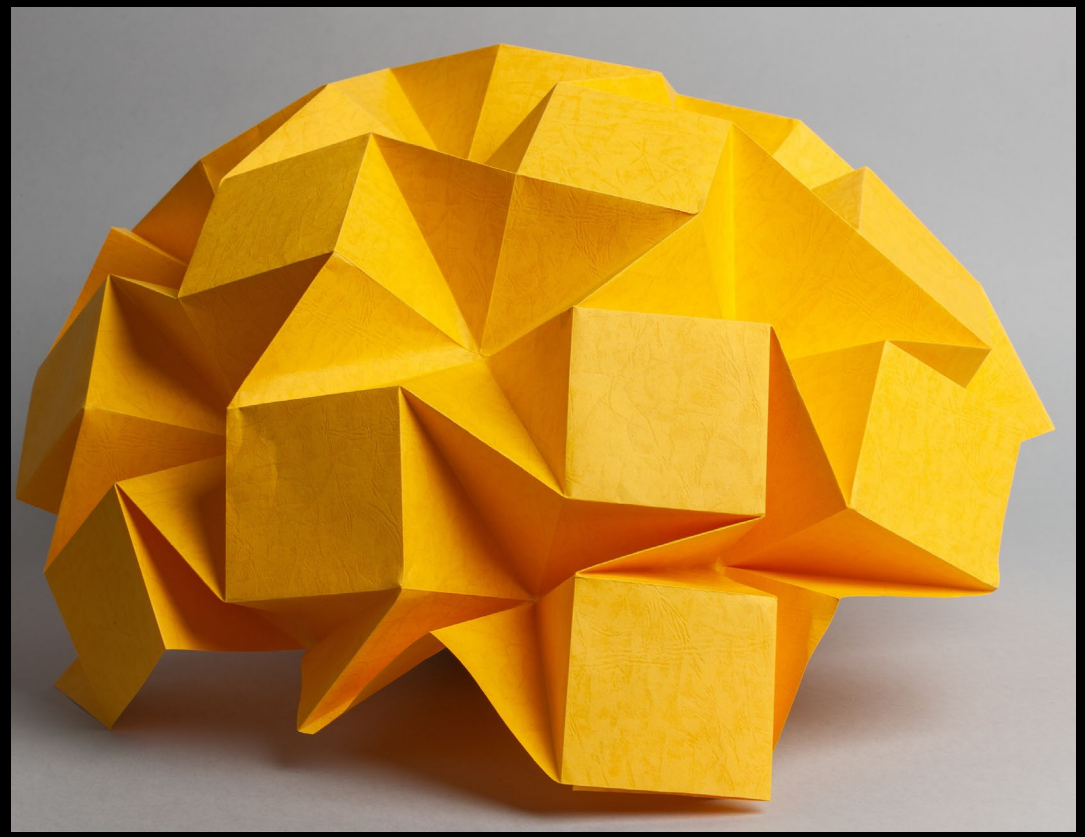
Less than 3% of preschool-aged children receive a diagnosis of ADHD

- 70-90% continue to meet diagnostic criteria in later childhood

Danielson et al, 2024; Law et al, 2014; Riddle et al, 2014


What do we know about the brain and ADHD?
Can that inform early identification?

Children and adults with ADHD have been found to have reduced brain volumes



Prefrontal cortex (PFC) involved in executive functioning (planning, decision making, working memory, impulse control).

Parieto-temporal region is involved in attention.

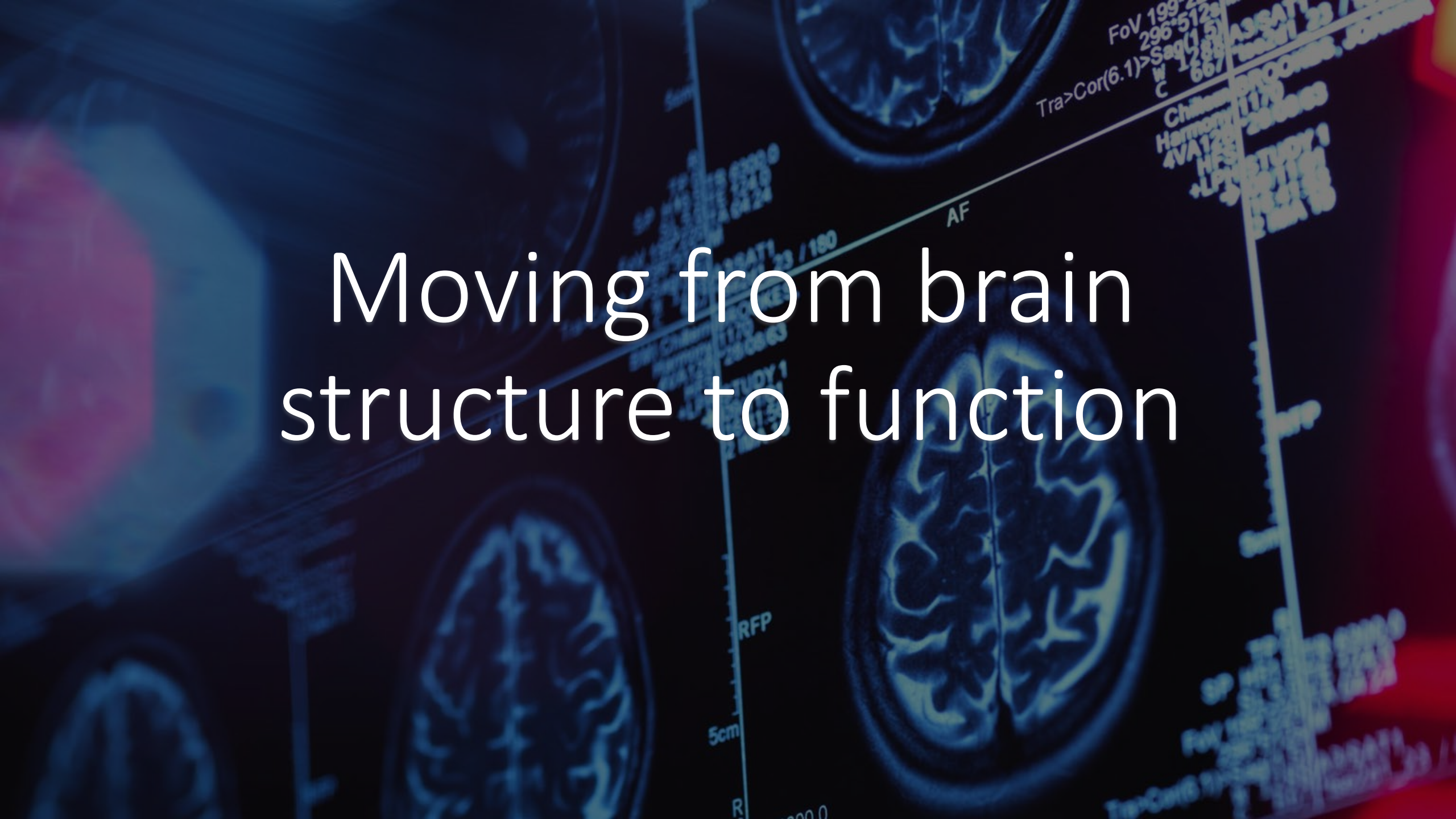
Friedman & Rapoport (2015) *Current opinion in neurobiology;*
Hoogman et al. (2019) *American Journal of Psychiatry*

Brains of children with ADHD appear younger than same age peers without ADHD

Longitudinal MRI studies have identified **delayed brain maturation**

Brains of children with ADHD appear ~3 years younger than children without ADHD

Shaw et al. (2007) *Proc Natl Acad Sci USA*; Shaw et al. (2012) *Biol Psychiatry*



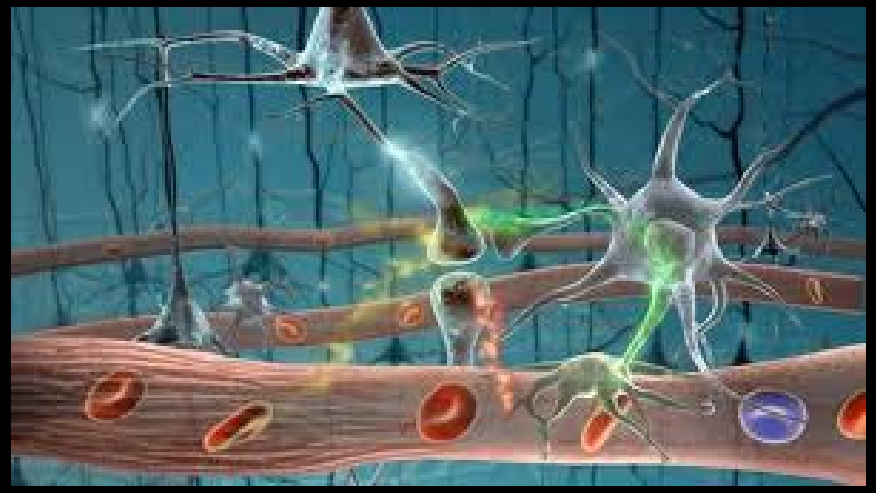
Moving from brain structure to function

How is brain activity measured?

Neurons use oxygen to produce energy needed to function.

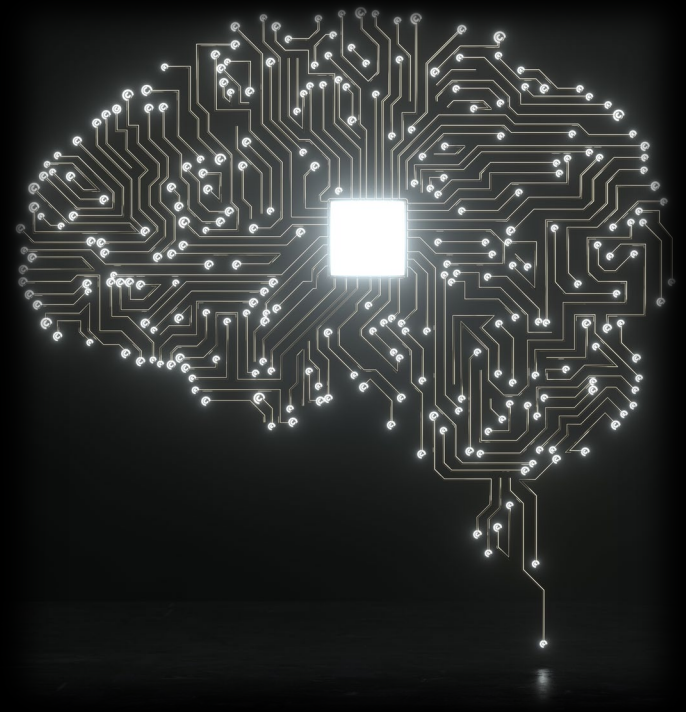
As neurons increase firing rates, the oxygen consumption also increases.

By detecting changes in oxygen levels in the brain we can identify which areas have neurons that are active.



Children and adults with ADHD have altered brain function

Individuals with ADHD have been found to have altered brain activity in areas involved in the control of attention, cognition, and inhibitory control.



Yang et al. (2025) *Translational Psychiatry*,

What about preschool-aged children?

This is a period of rapid brain development

- Ideal for interventions

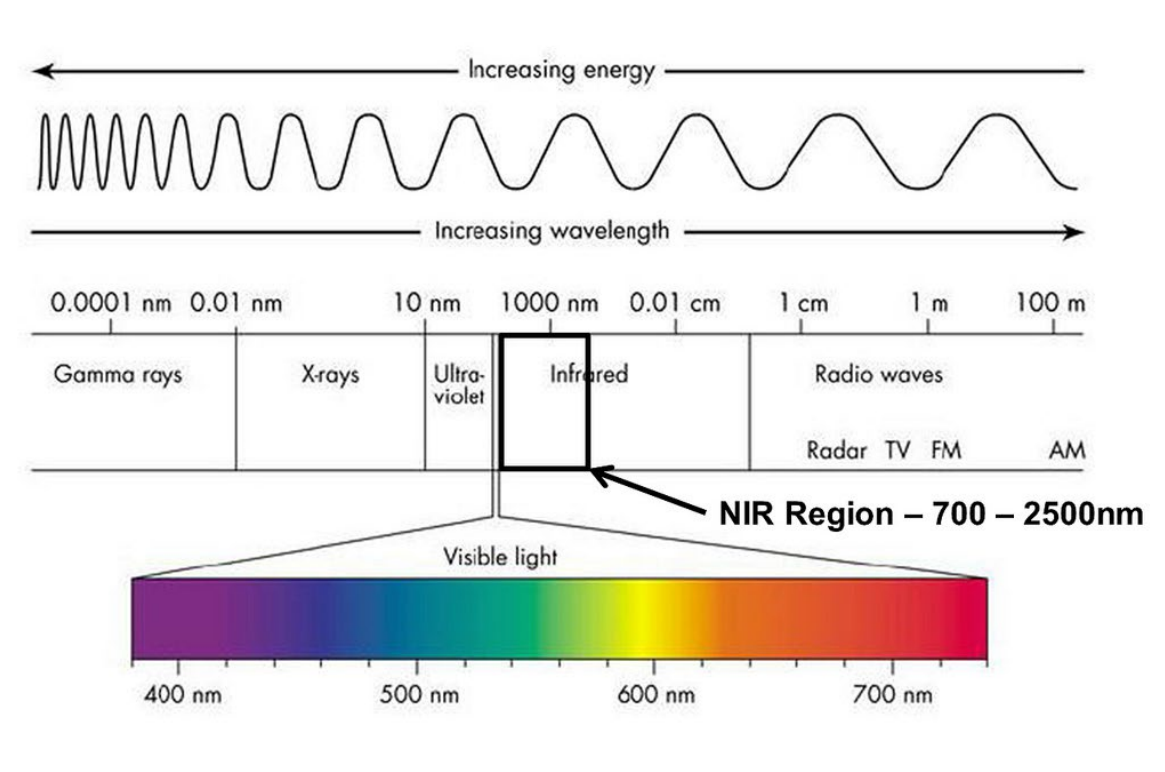
Very few MRI studies with preschool-aged children with ADHD

- Limited due to motion

It is **not yet known** if altered neural connectivity can be detected **before** the onset if childhood ADHD

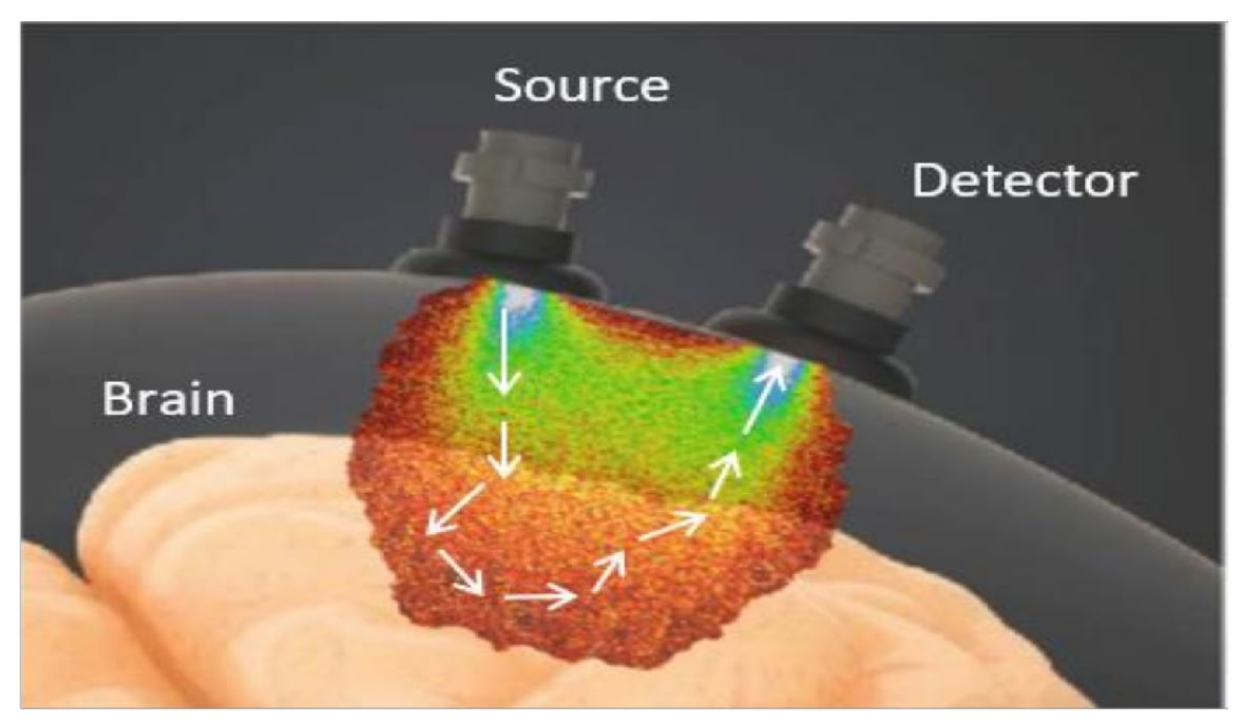
Functional Near-Infrared Spectroscopy (fNIRS)

Near-Infrared Light



Lloyd-Fox et al., 2010; Ferrari & Quaresima, 2012

Near-Infrared Spectroscopy (NIRS)



- Safe (no radiation)
- Sources emit light and detectors absorb light
- The penetration range of light in the brain is about 3 cm (limited to cortical structures)

Lloyd-Fox et al., 2010; Ferrari & Quaresima, 2012

BBRF 2021
Young Investigator Award

Examine prefrontal cortex and the dorsal attention network in preschool-aged children with and without familial risk for ADHD

fNIRS during two lab visits at 4 and 5 years old

→Watching a computer screen with moving images and music (inscapes)

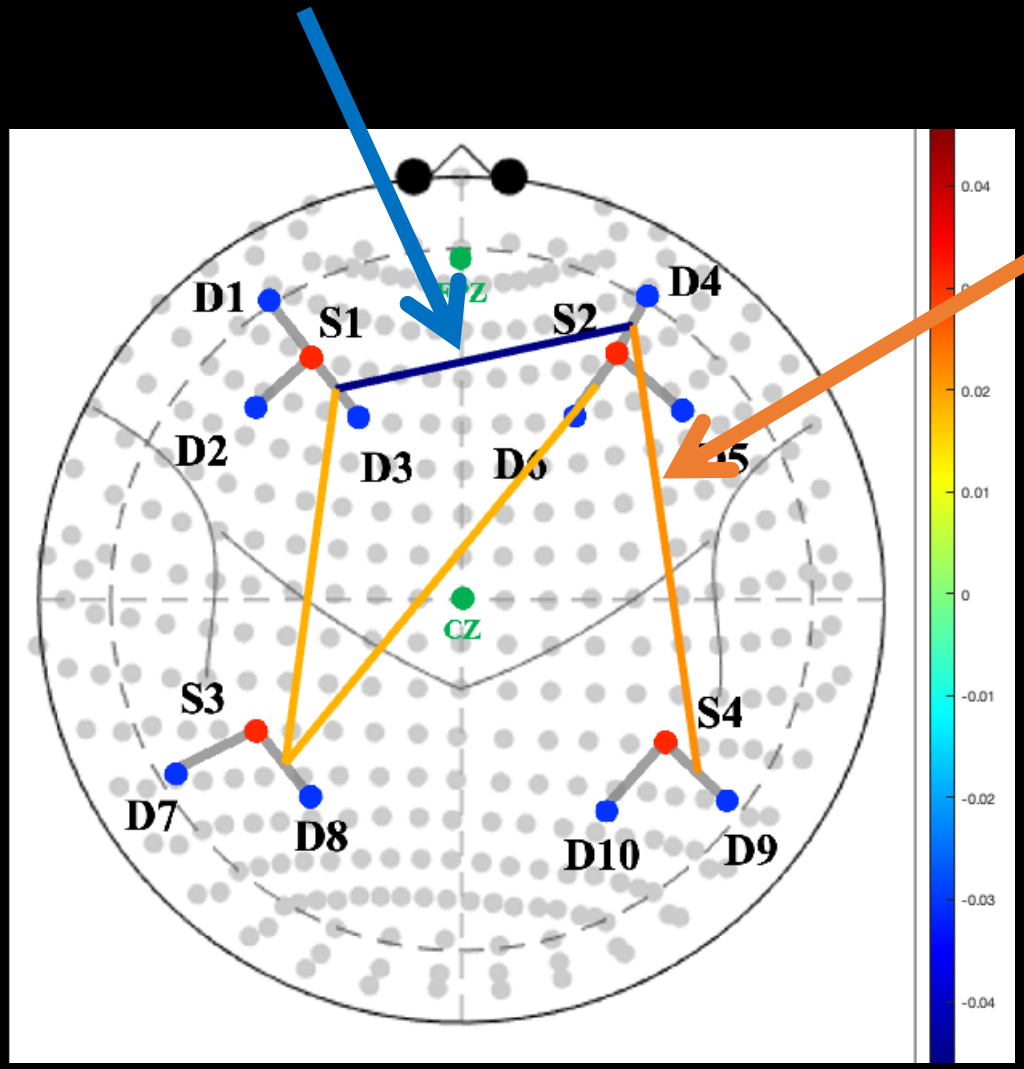
Project Aims

1

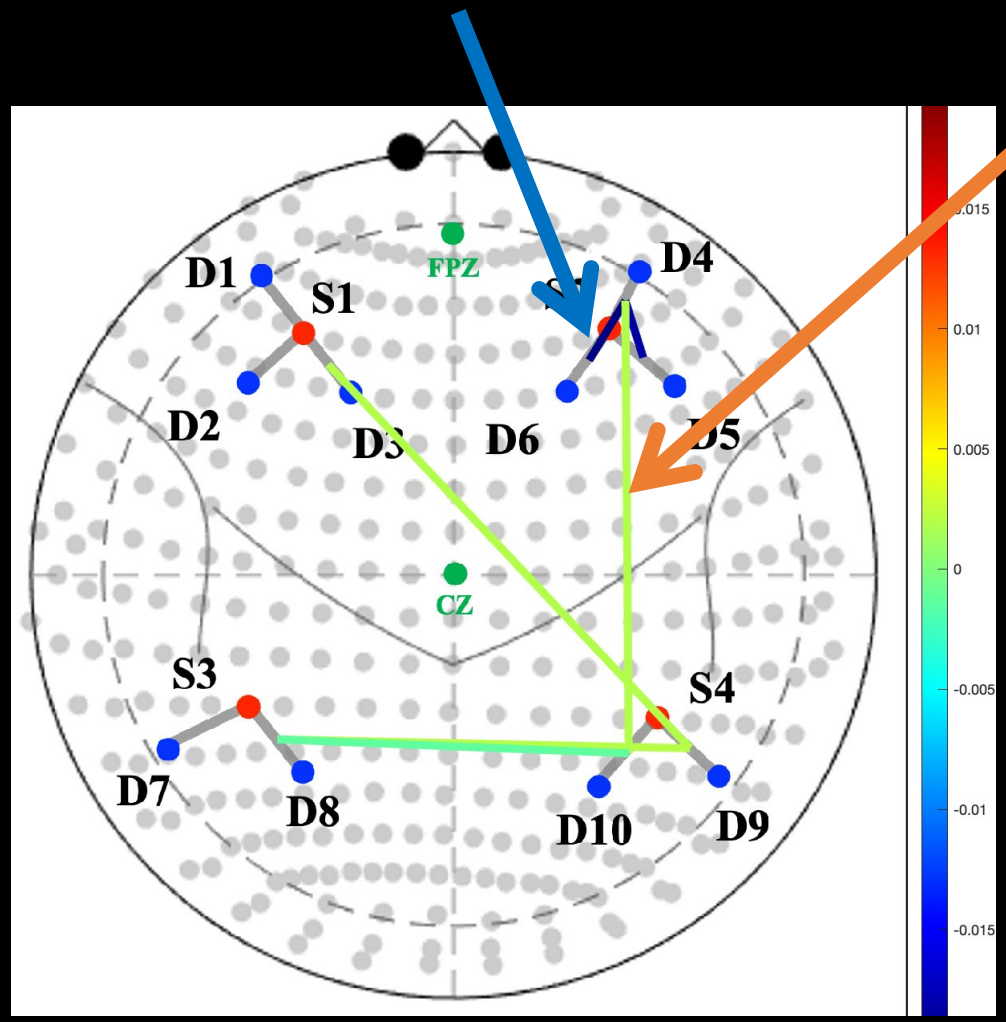
Compare brain activity of children born to parents with vs. without ADHD.

2

Examine brain activity at age 4 as a predictor of ADHD symptoms at age 5.



Offspring of parents with ADHD require greater connectivity between the dlPFC and dorsal attention network to stay engaged.



Greater connectivity between the dlPFC and parietal cortex during an engaging task at age 4 is associated with more ADHD symptoms a year later.

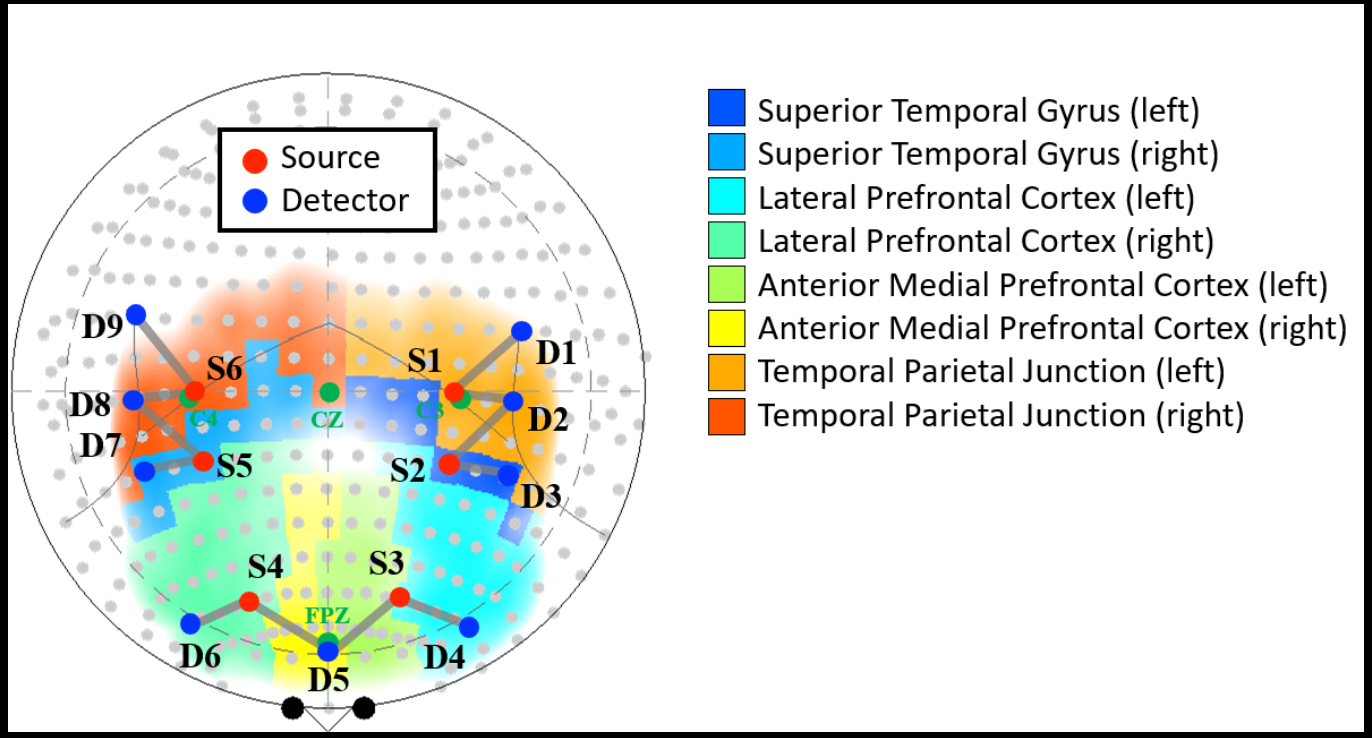
AtHENS Study

Attention, Hyperactivity, and Early Neurodevelopment Study

NIMH R01MH138380

Can we identify even earlier markers of risk before the onset of ADHD symptoms?

We have found similar brain activity among toddlers with greater inattention.



NIMH R01MH113777
Principal Investigator:
Judith K. Morgan, PhD

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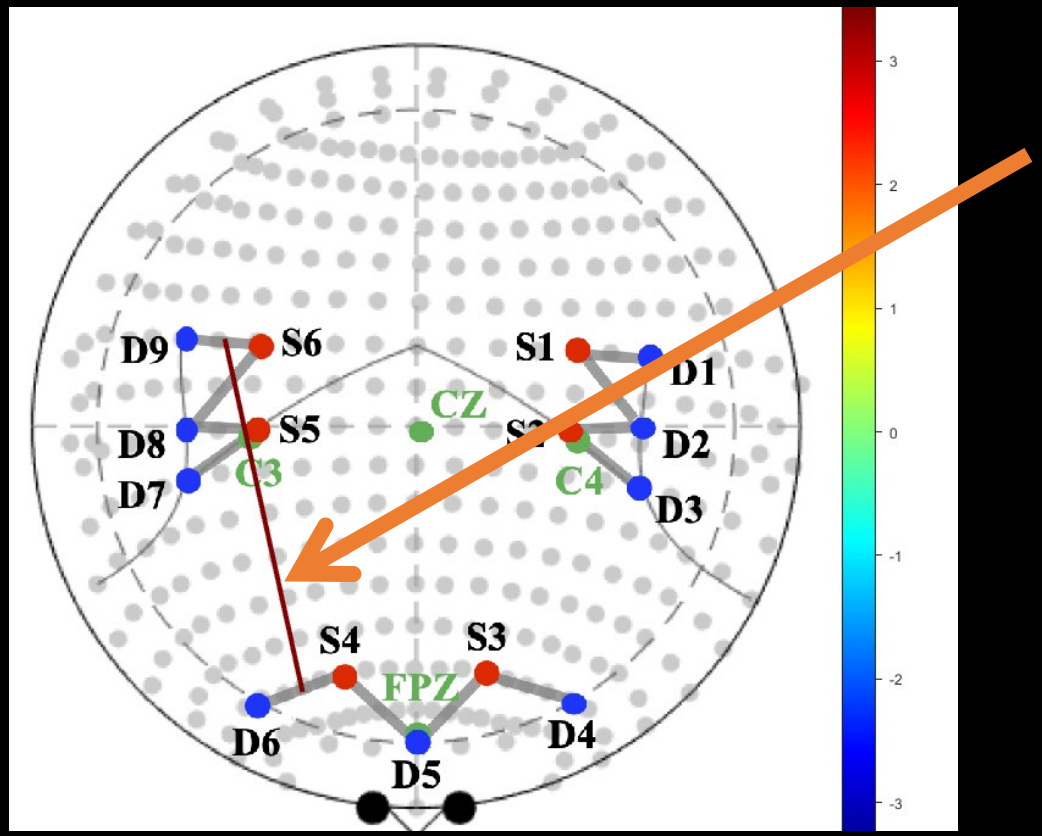

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Infant Attention Task

PARIS & New(born) PARIS Studies

151 mother-father-infant triads

Parental ADHD diagnosis as determined by semi-structured clinical interview:

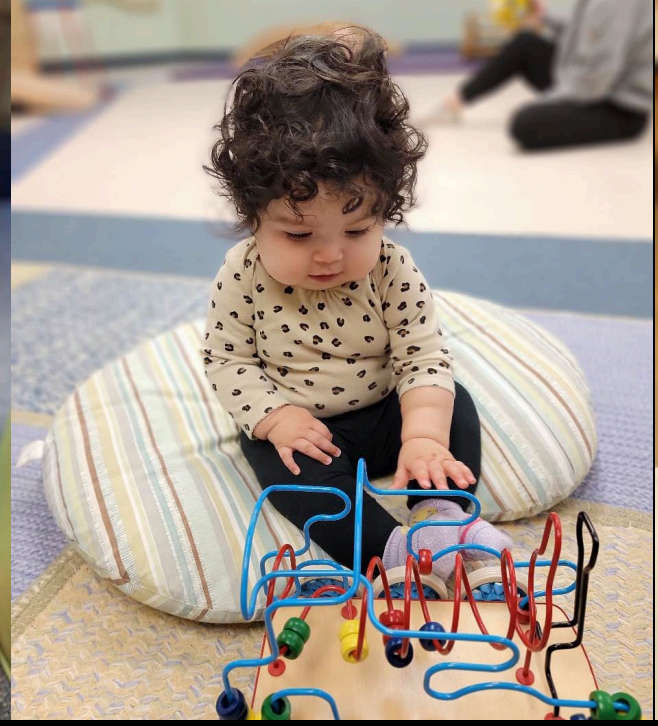
71 High Risk for ADHD Infants

At least 1 parent with ADHD

80 Low Risk for ADHD Infants

Neither parent had ADHD






Infant Looking Time

Looking Time = Attention

What is Habituation?

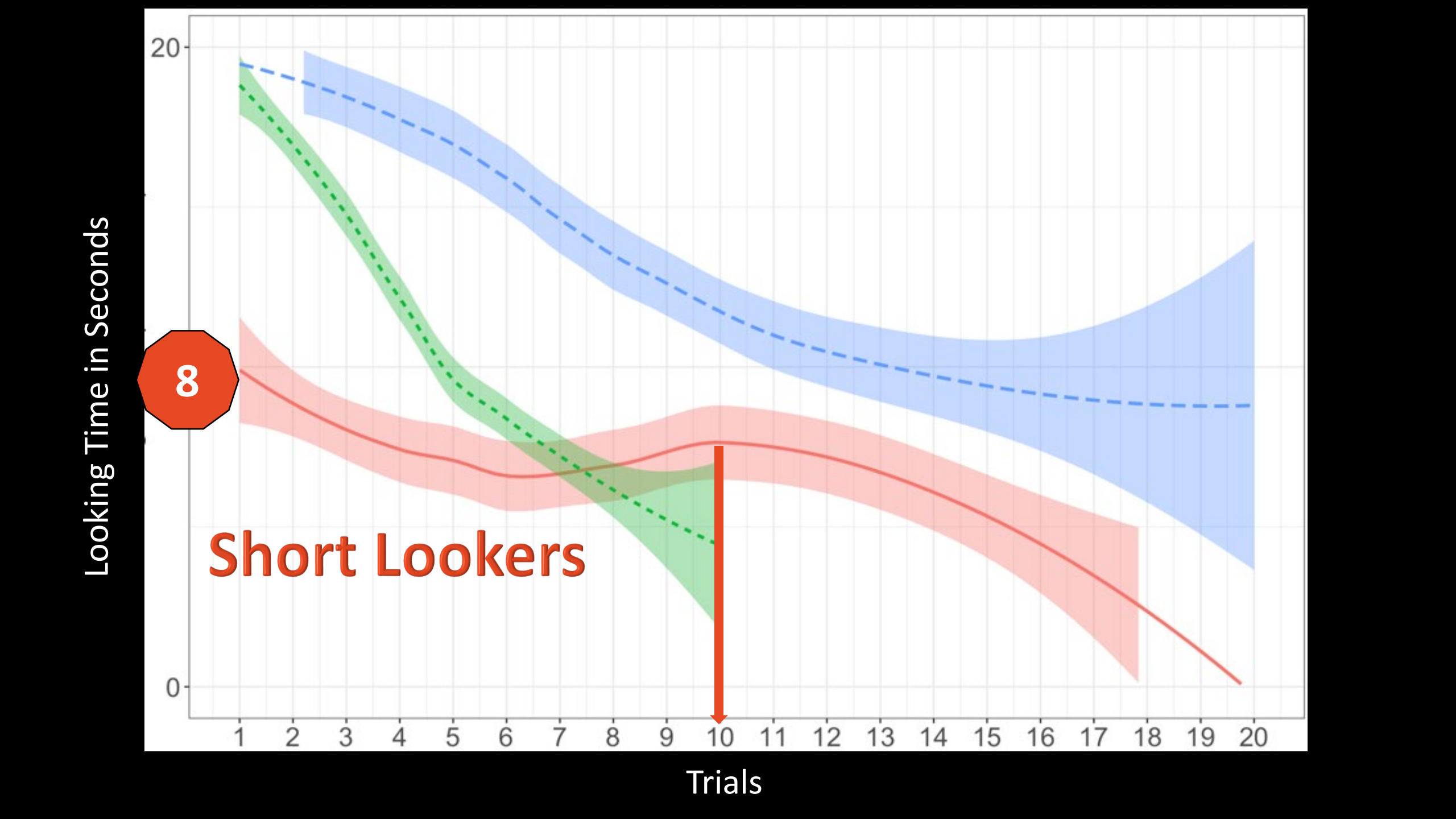
A diminished response to a frequently repeated stimulus

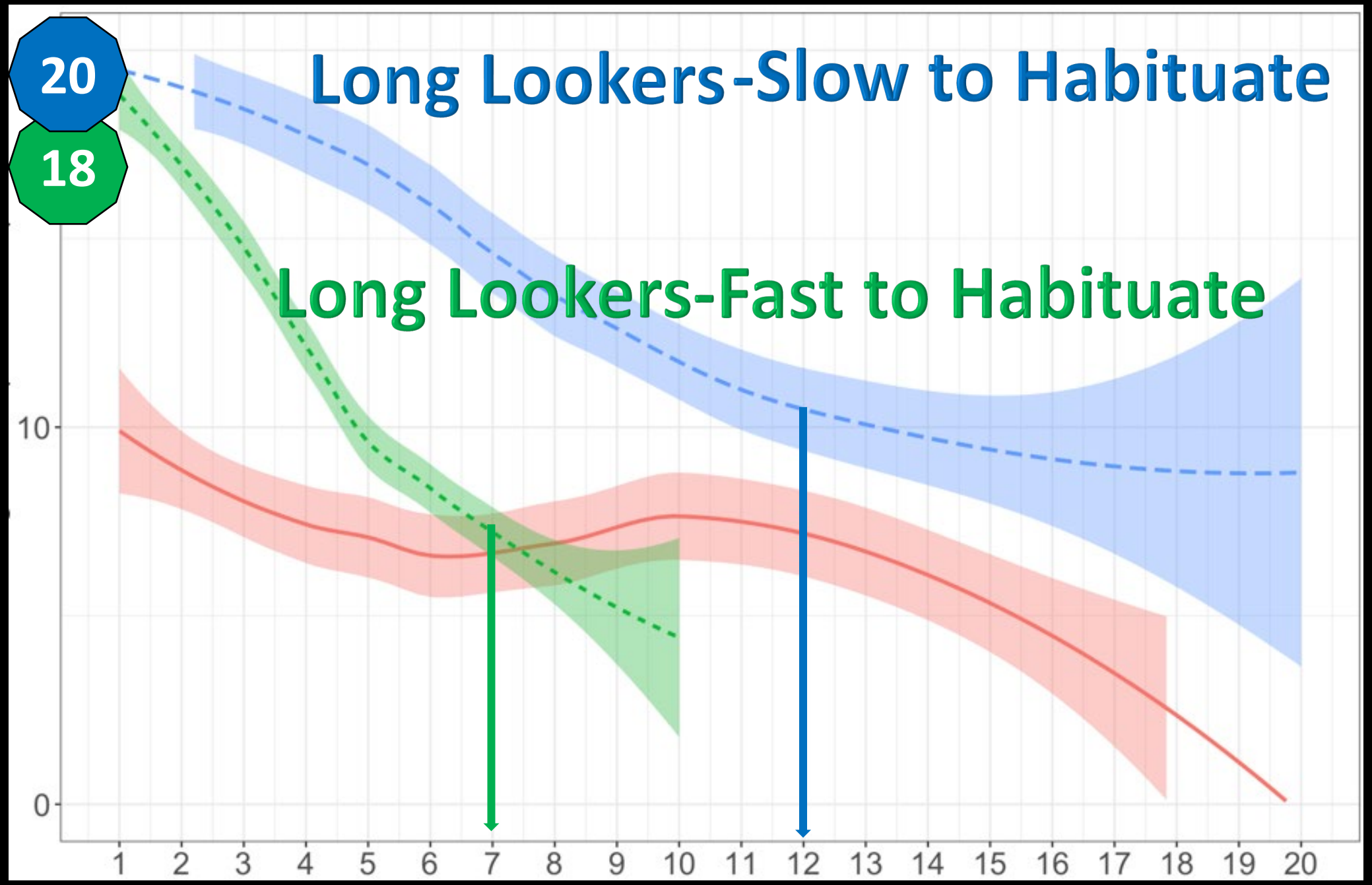
Faster Habituation = Greater Attention

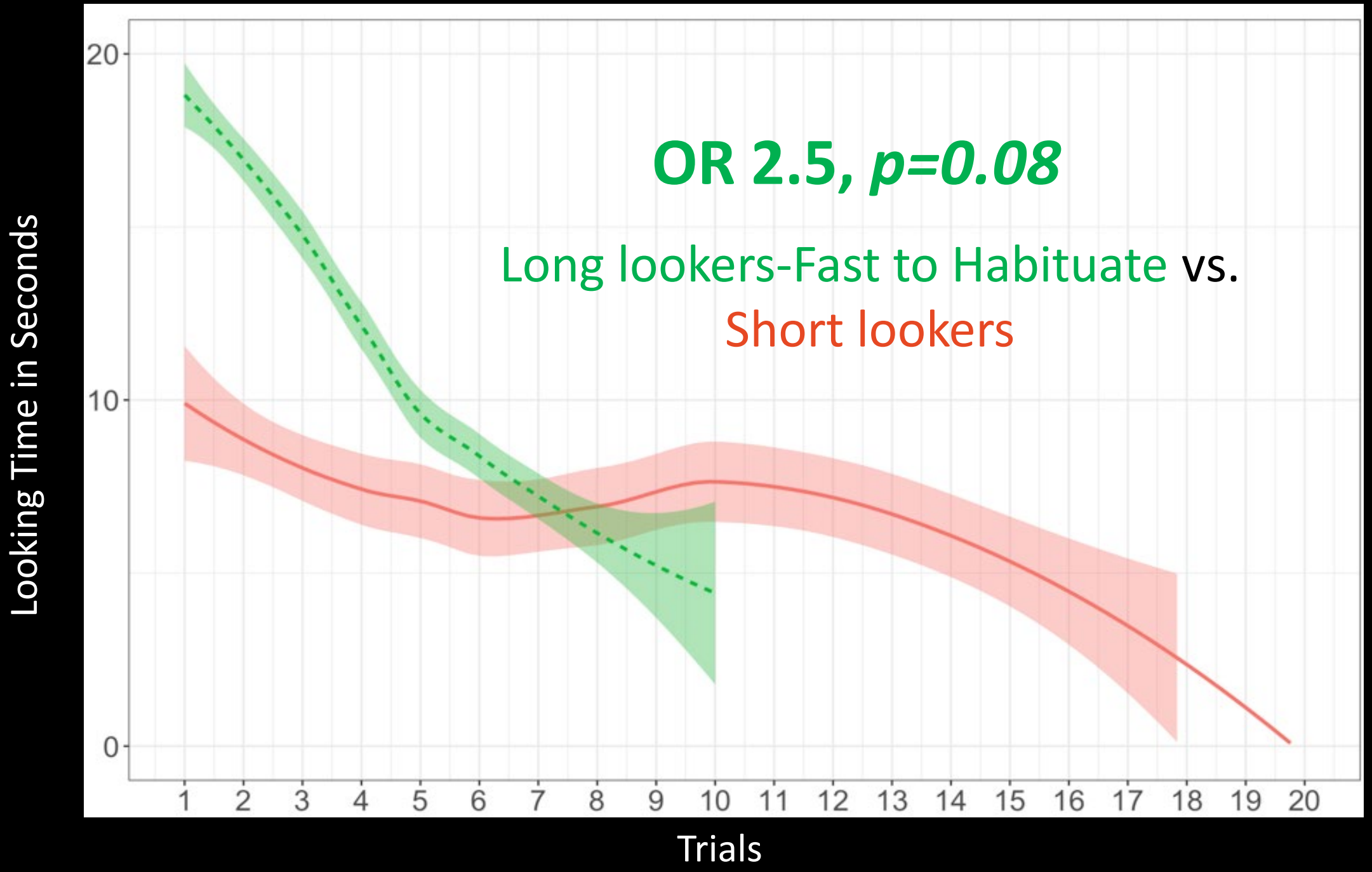
Task Design

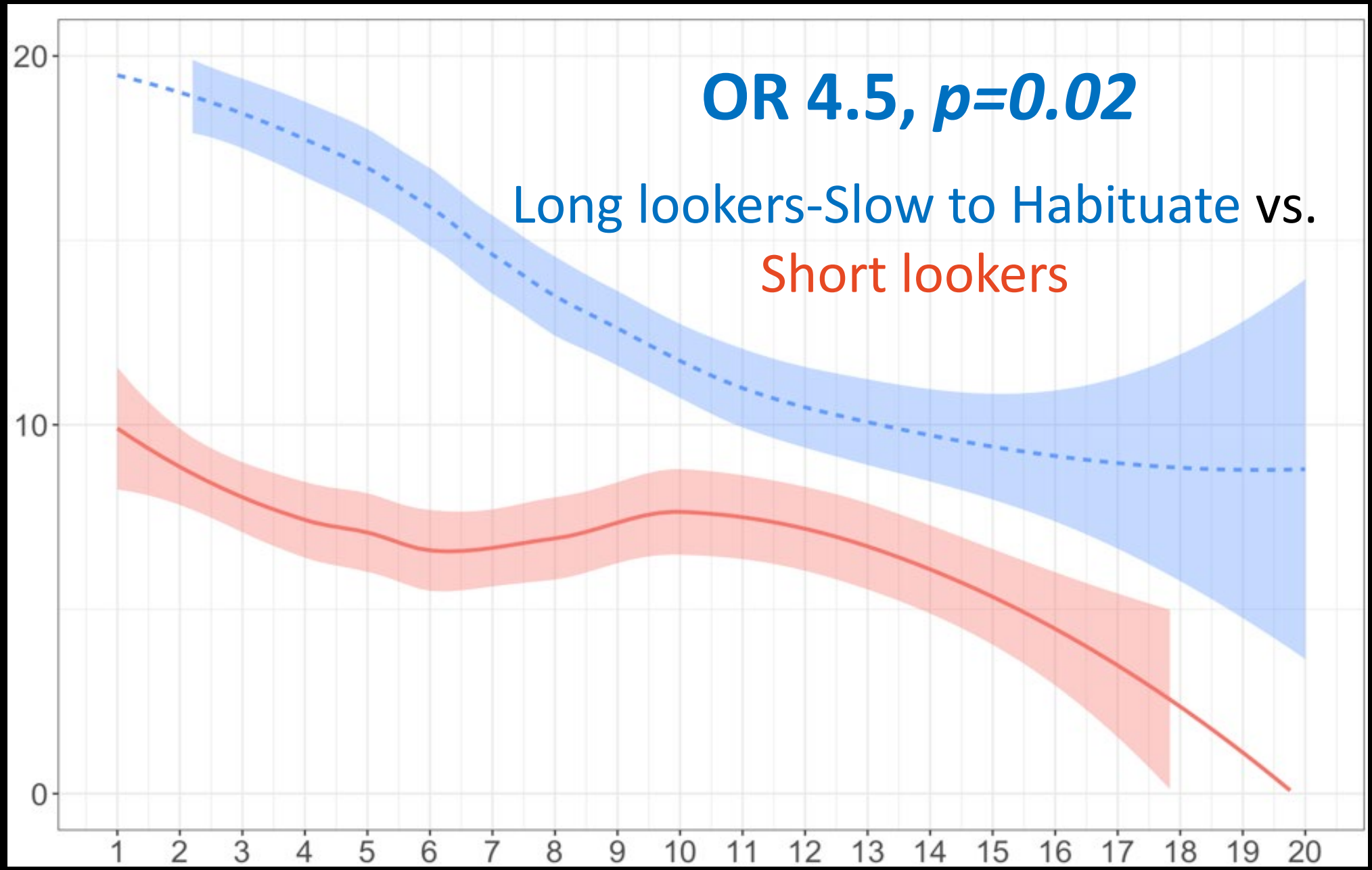
- **Up to 20 test trials** (max of 20 seconds each)

Habituation is achieved when looking time drops to **less than ½ of the first three trials averaged**


Looking Time in Seconds
20
0
8
Short Lookers
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Trials


20
18
Long Lookers-Slow to Habituate
Long Lookers-Fast to Habituate
Looking Time in Seconds
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trials


Looking Time in Seconds
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trials
OR 2.5, p=0.08
Long lookers-Fast to Habituate vs.
Short lookers


OR 4.5, p=0.02
Long lookers-Slow to Habituate vs.
Short lookers
Looking Time in Seconds
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trials

Habituation patterns in infancy might be an early marker of risk for childhood ADHD

Next Steps…

Longitudinal Follow Up

Infant Task Performance in relation to Brain Connectivity & Development


Teamwork

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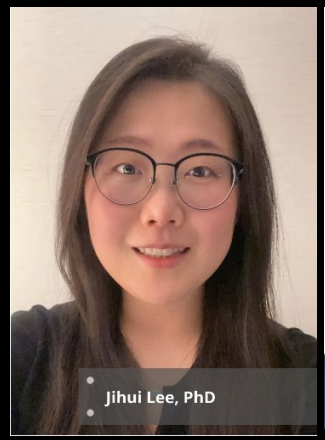

Questions