

The Brain-Behavior Connection

In Children with ADHD

https://youtu.be/4z9ZM_q14pY

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meet today's expert speaker:

Joel Nigg, Ph.D.



[Joel Nigg](#), Ph.D., is a clinical psychologist and a professor in the departments of psychiatry and behavioral sciences at OHSU. He directs the OHSU ADHD Research program and is also director of the division of psychology. Author of *What Causes ADHD? Understanding What Goes Wrong and Why*. Dr. Nigg has published nearly 200 peer-reviewed scientific papers related to the neuropsychological, cognitive, and temperamental correlates of child ADHD, to ADHD genetics, and in particular for this talk, to MRI-based research and theoretical interpretations of brain development in ADHD.

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OUTLINE

- Neuroscience basics and relevance to ADHD
- Top-down/bottom-up self-regulation of attention, emotion, behavior
- Attention and ADHD brain
- Emotion and ADHD brain
- Individual variation in ADHD
- Summary

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HOW DOES THE BRAIN WORK IN CONCEPT?

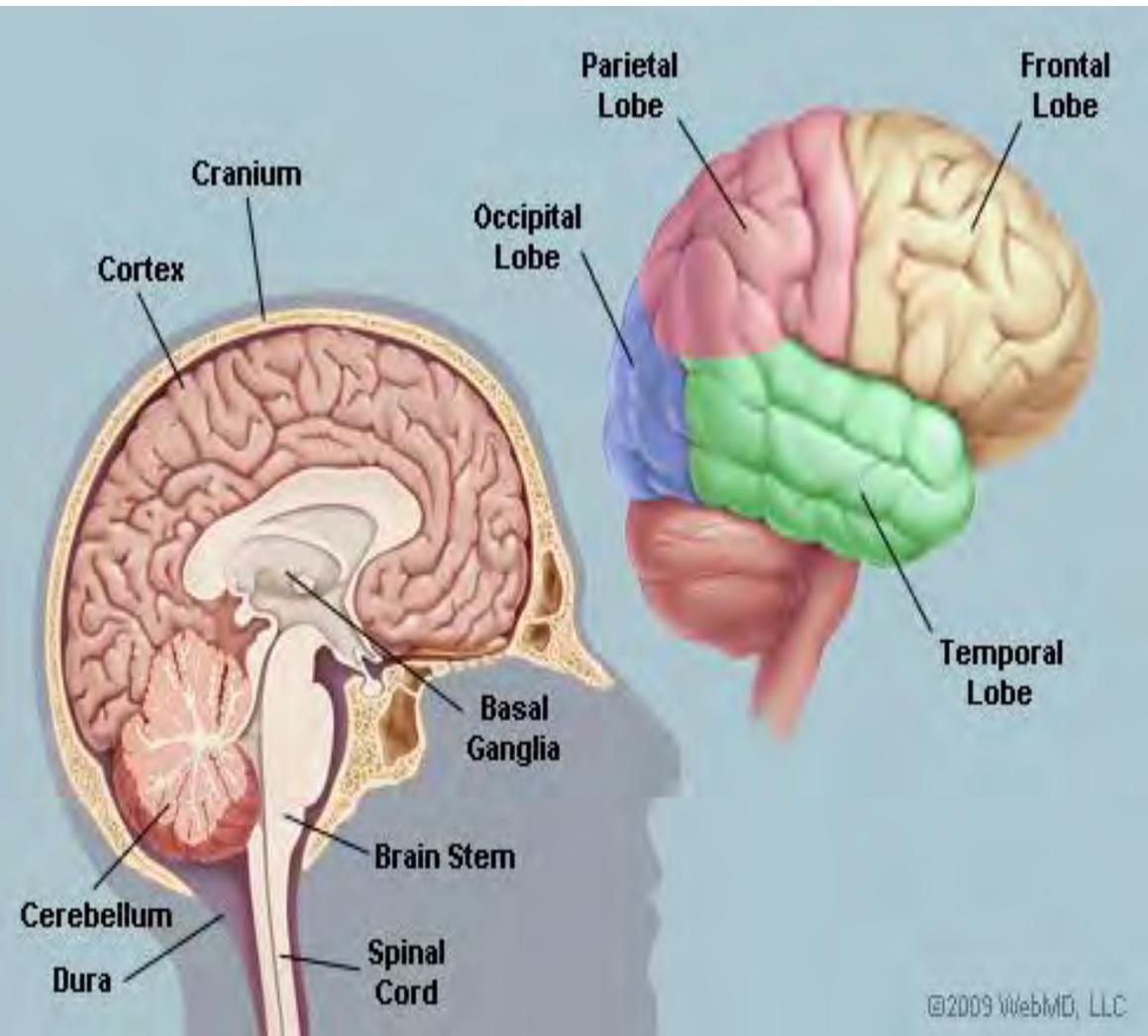
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Orientation: Basic brain map



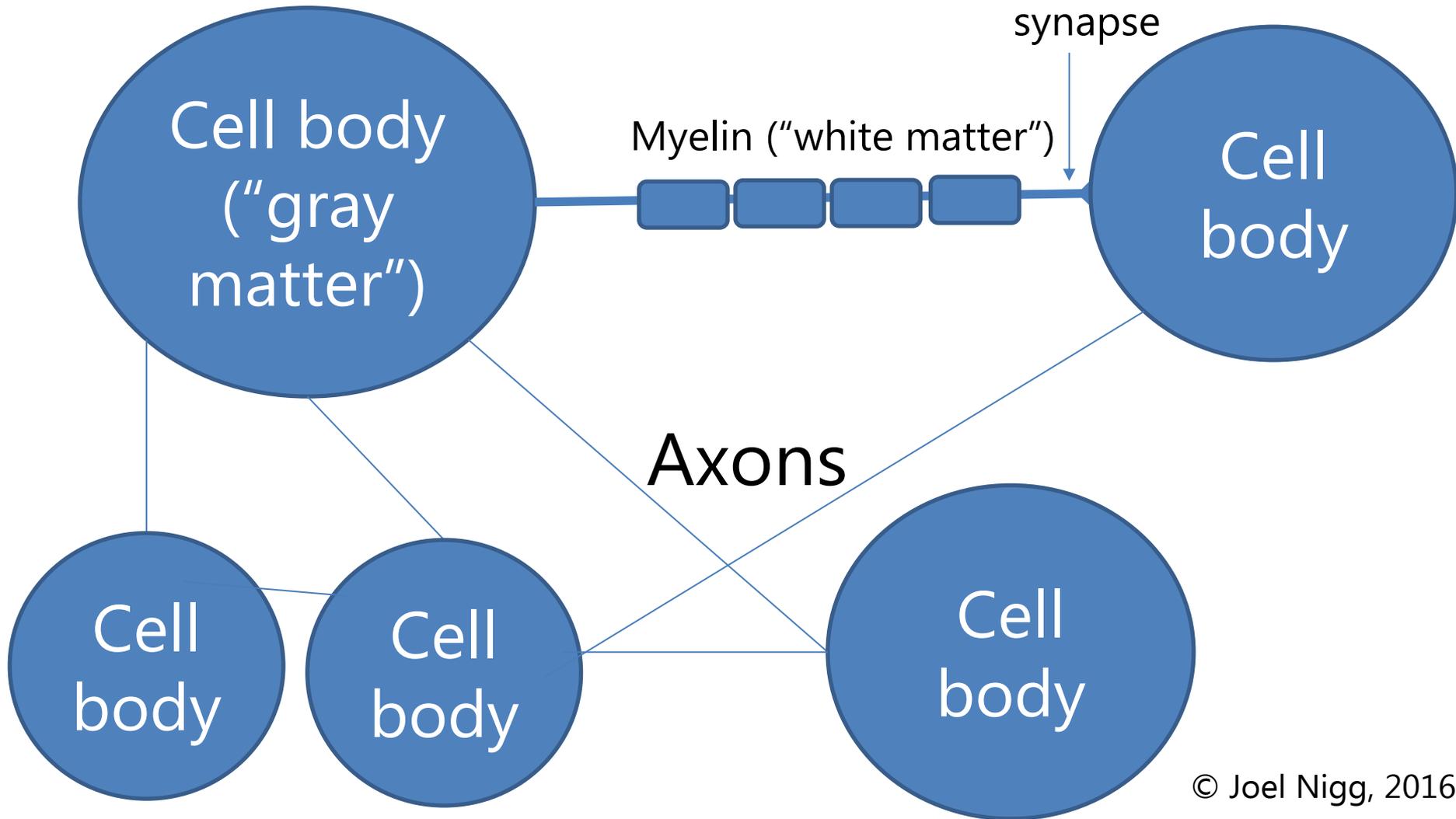
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Neuron and Network Concept



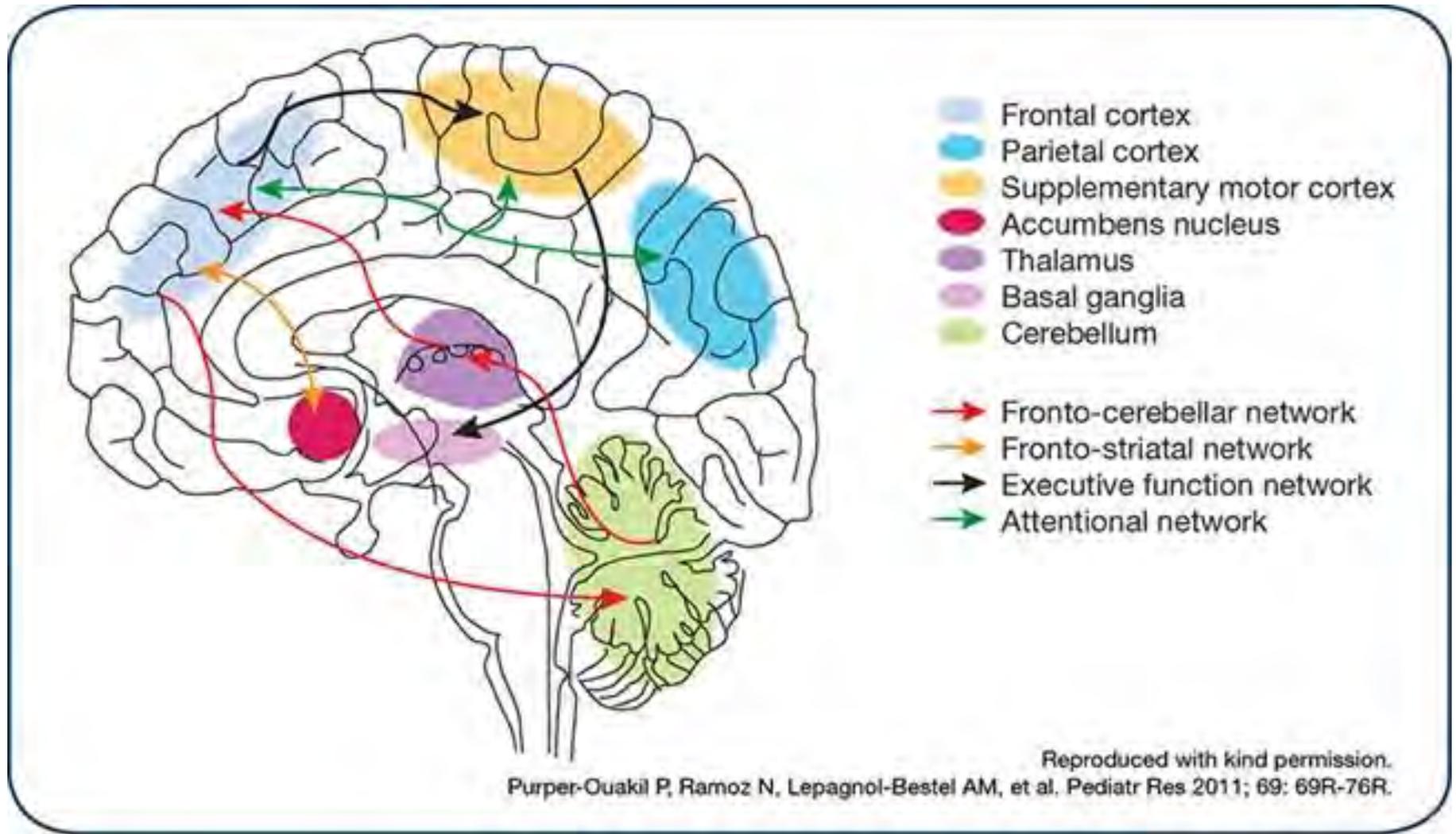
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Critical circuits and networks ADHD Brain



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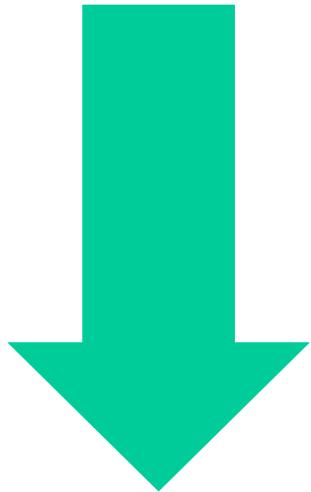
HOW DOES IT WORK IN PRACTICE FOR SELF-REGULATION? PRINCIPLE OF TOP- DOWN/BOTTOM UP BALANCING

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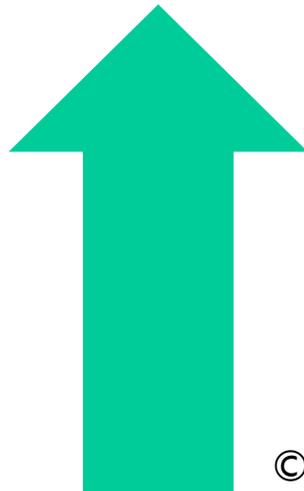
"Normative Adjustment"



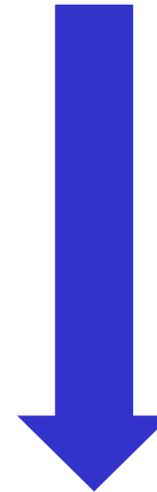
Top
down
control



Bottom up
emotional
reactivity



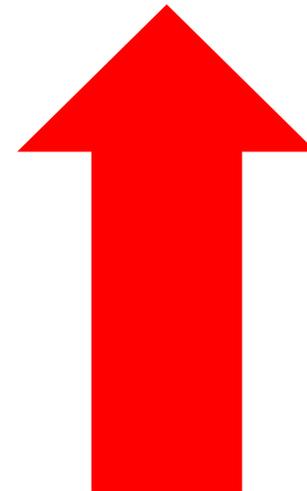
"Schematic ADHD"



Top
down
control



Bottom up
emotional
reactivity



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SELF-REGULATION OF ATTENTION AND BEHAVIOR IN ADHD BRAIN

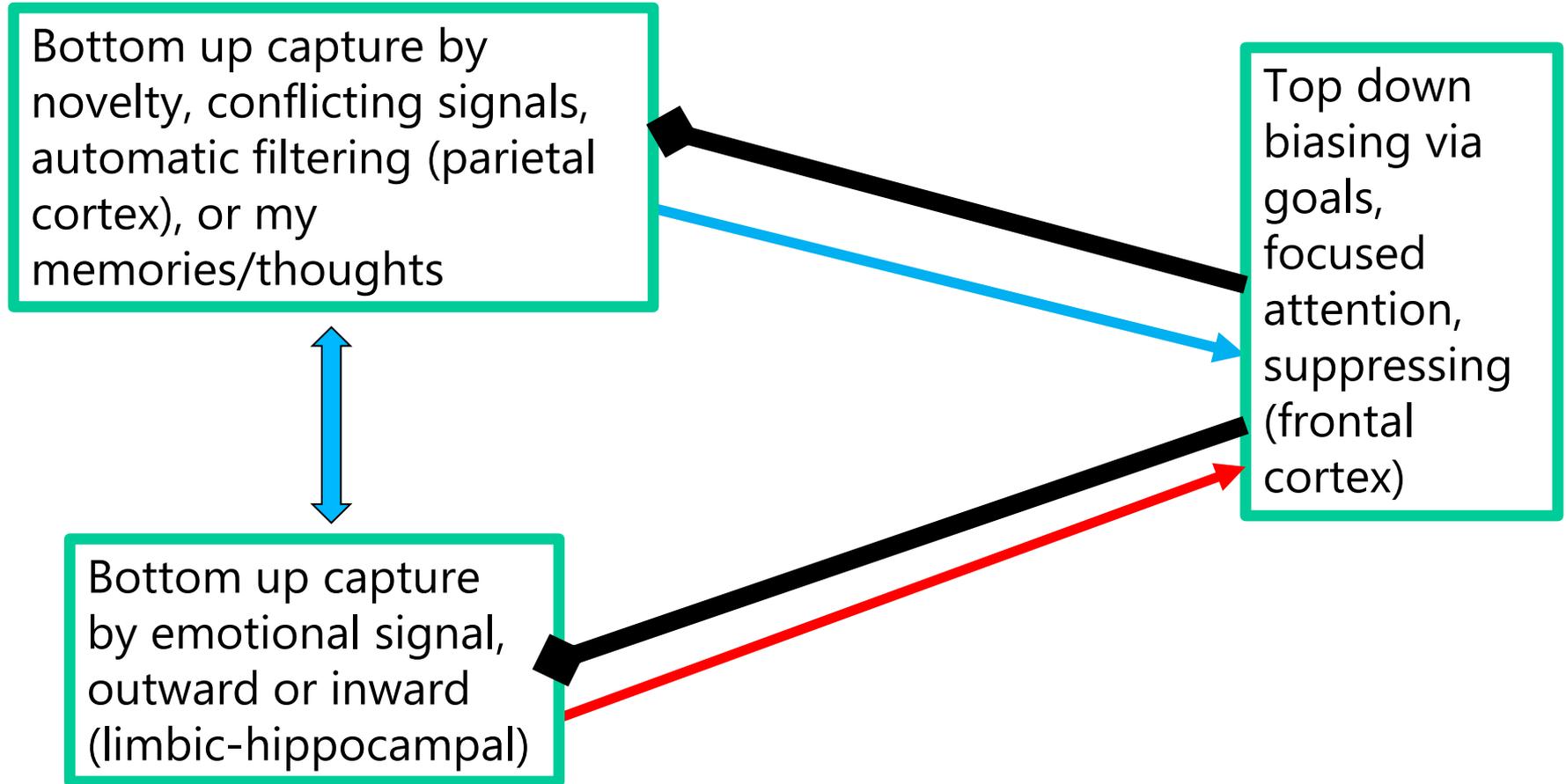
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A model of attentional and behavioral self-regulation in the brain



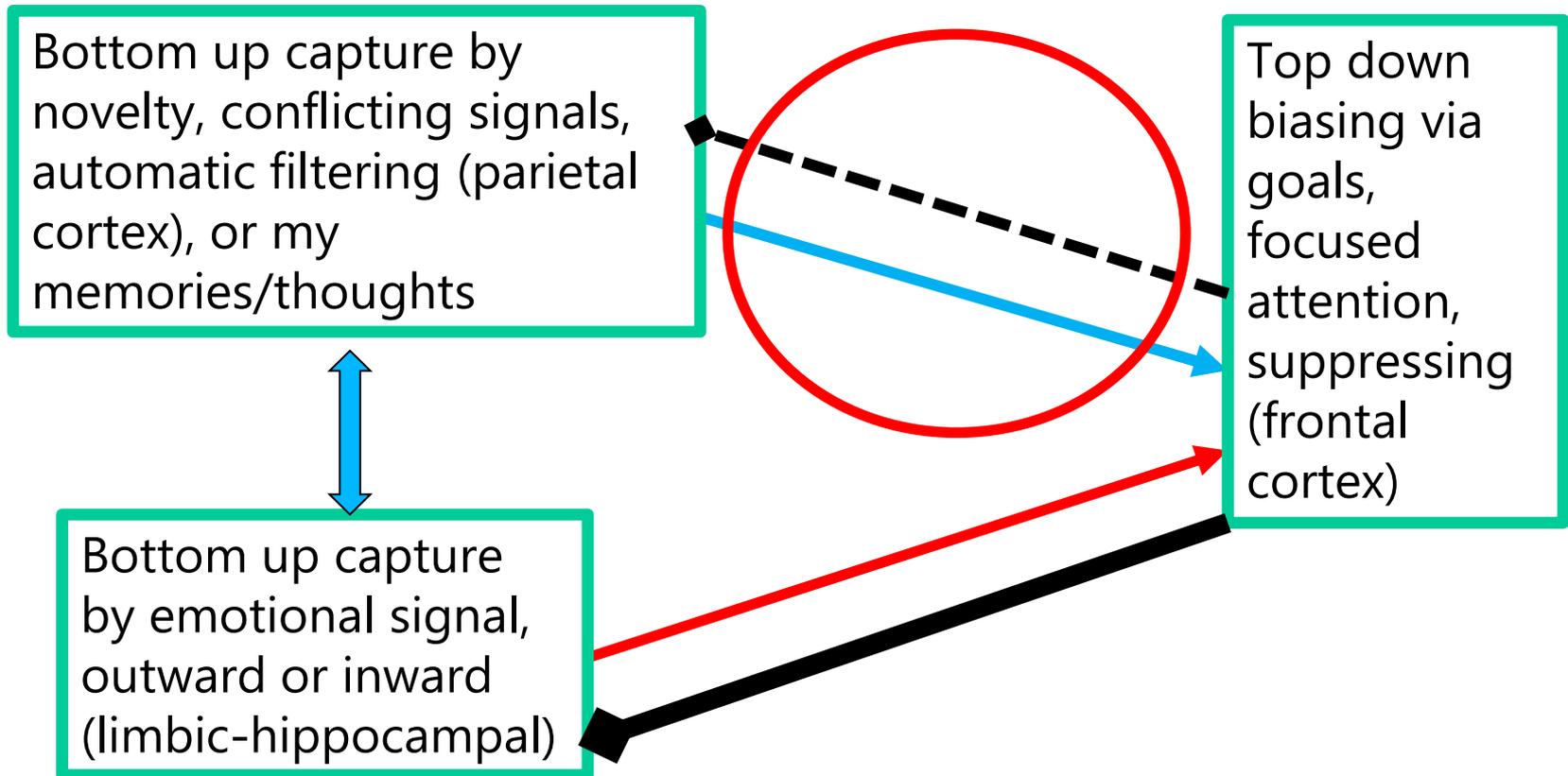
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A model of attentional and behavioral self-regulation in the brain: ADHD Model of weakened PFC-default connectivity



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HOW DOES SCIENCE SUPPORT THIS MODEL IN ADHD?

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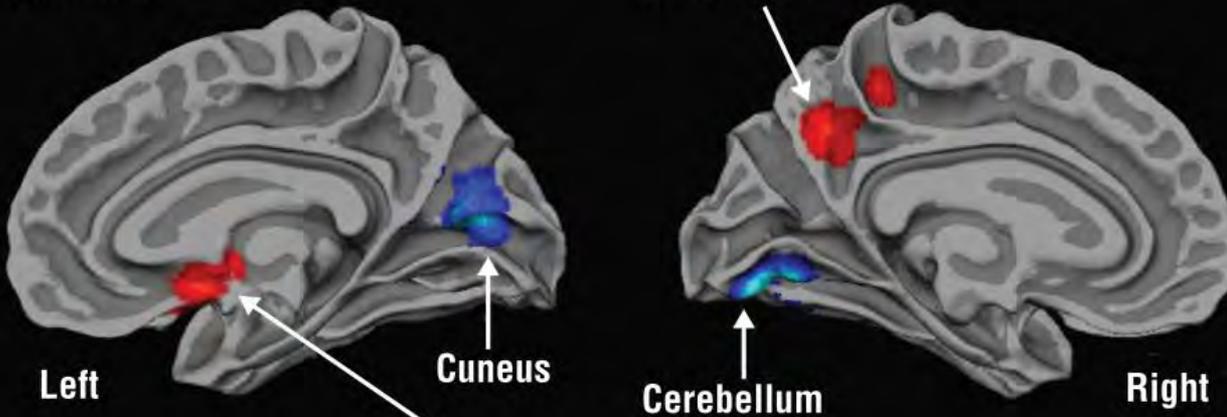
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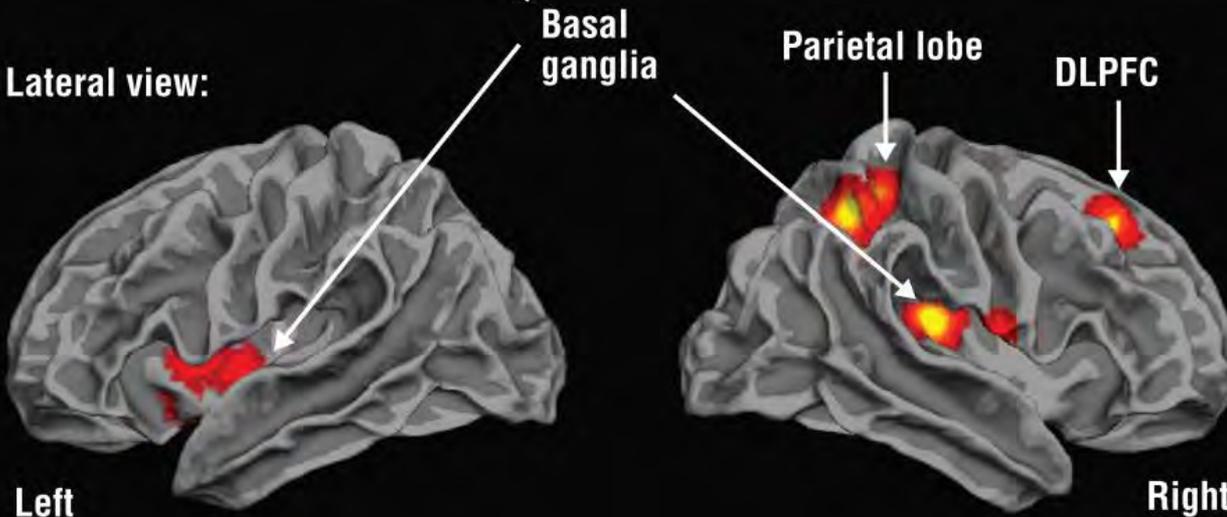
B Attention

Red: ADHD < CTR

Medial view:



Lateral view:



Altered **task-based activation** in components of frontal-striatal (top-bottom) brain regulation networks during attention tasks in ADHD (pooled meta-analysis results).

 The **JAMA** Network

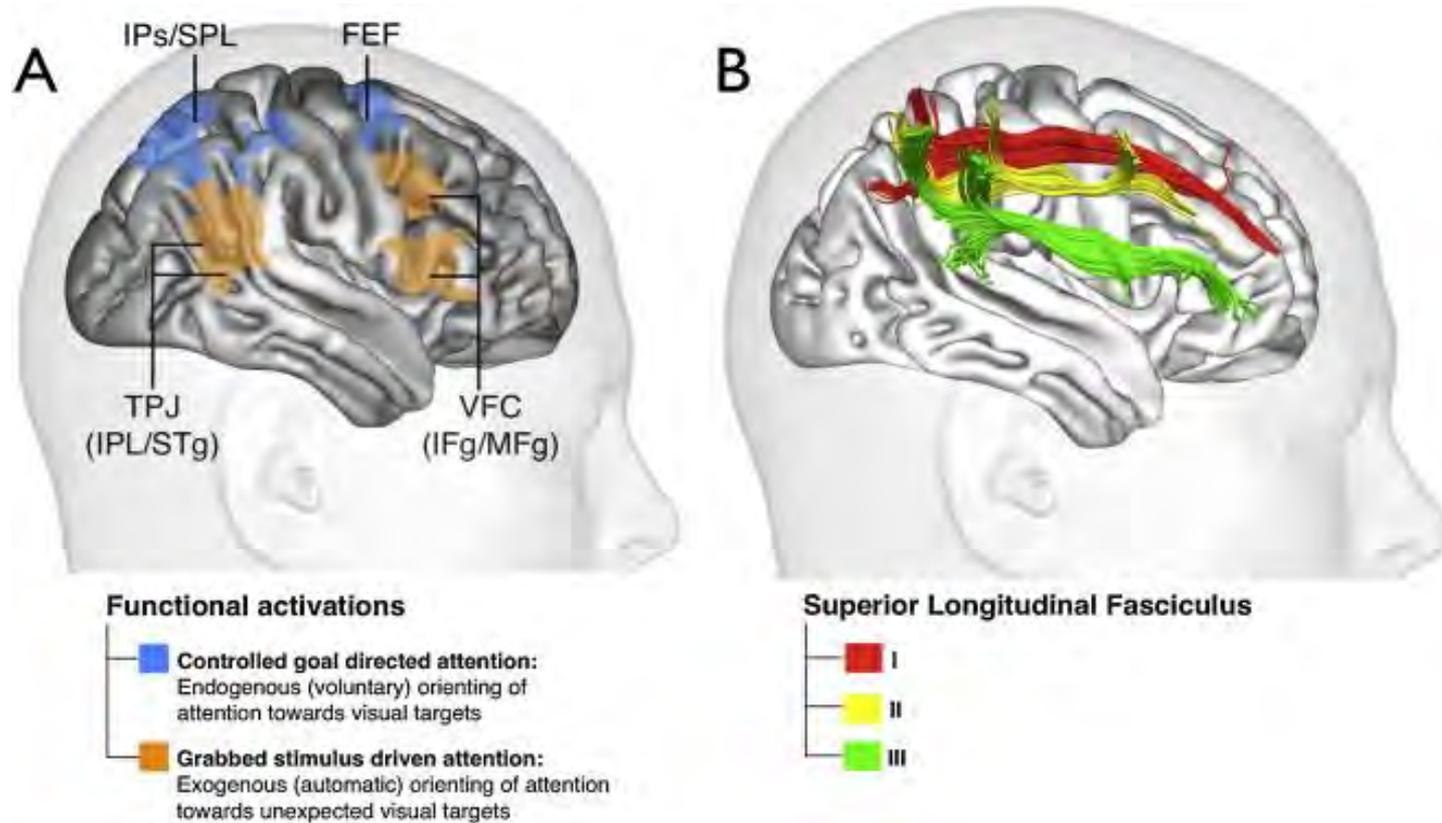
Source: Image is from Hart, Radua, et al. (2013) JAMA Psychiatry, Feb;70(2):185-98 (Fig 1). Copyright JAMA.

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ADHD: Reduced connectivity in attention networks



(A) Right-hemisphere networks of visuospatial attention, figure adapted by Chica et al from Corbetta and Shulman (2002).

(B) The three branches of the superior longitudinal fasciculus ; adapted by Chica et al from Thiebaut et al 2011.

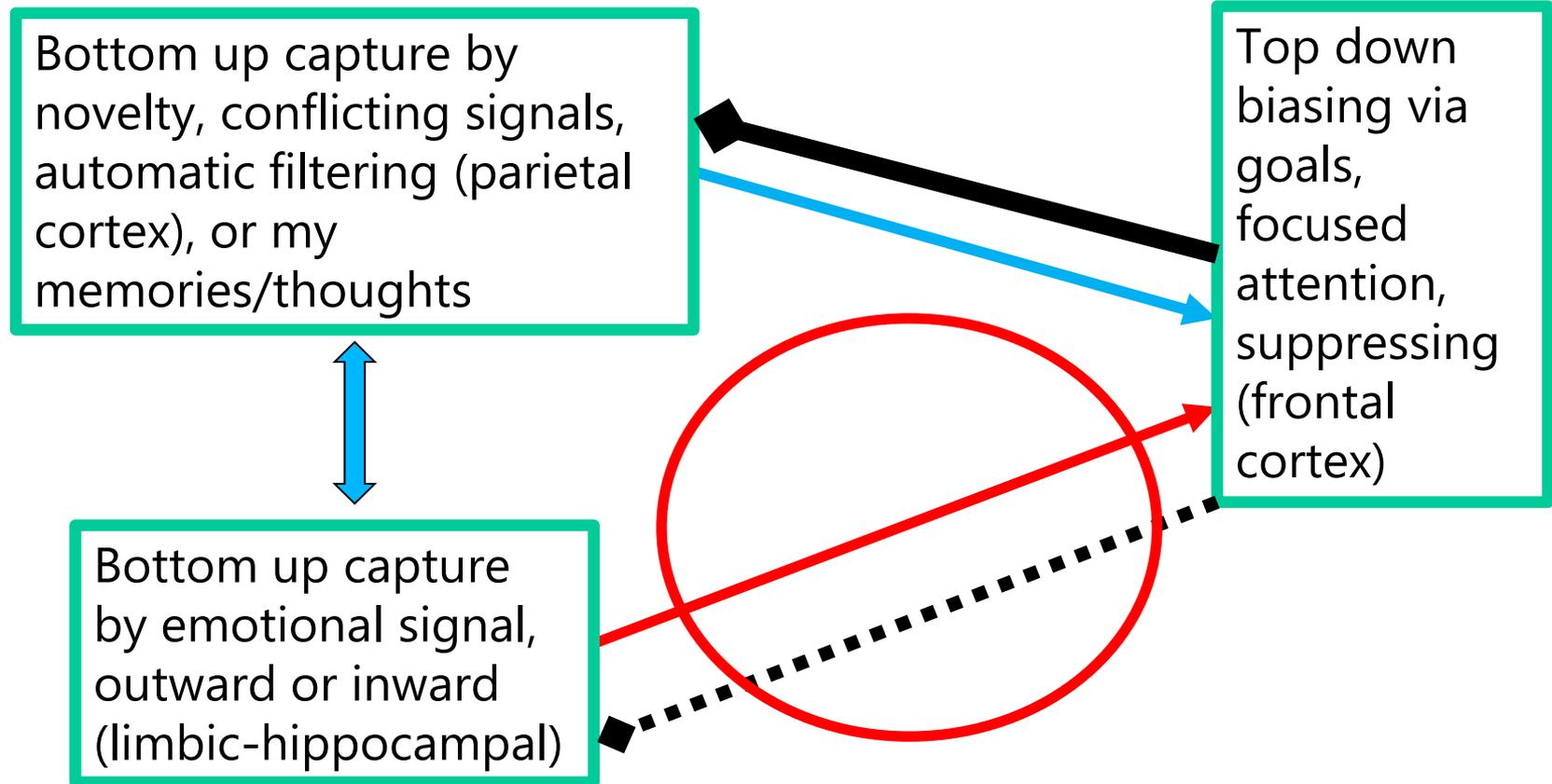
Reprinted from: Chica AB, Bartolomeo, P, Lupiáñez J (2013). Two cognitive and neural systems for endogenous and exogenous spatial attention. *Behavioral Brain Research*, 237, 107-123, Figure 3. Copyright *Behavioral Brain Research*

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An alternative model of attentional and *impulsivity* self-regulation in the brain: ADHD Model of weakened ACC/insula-amygdala connectivity



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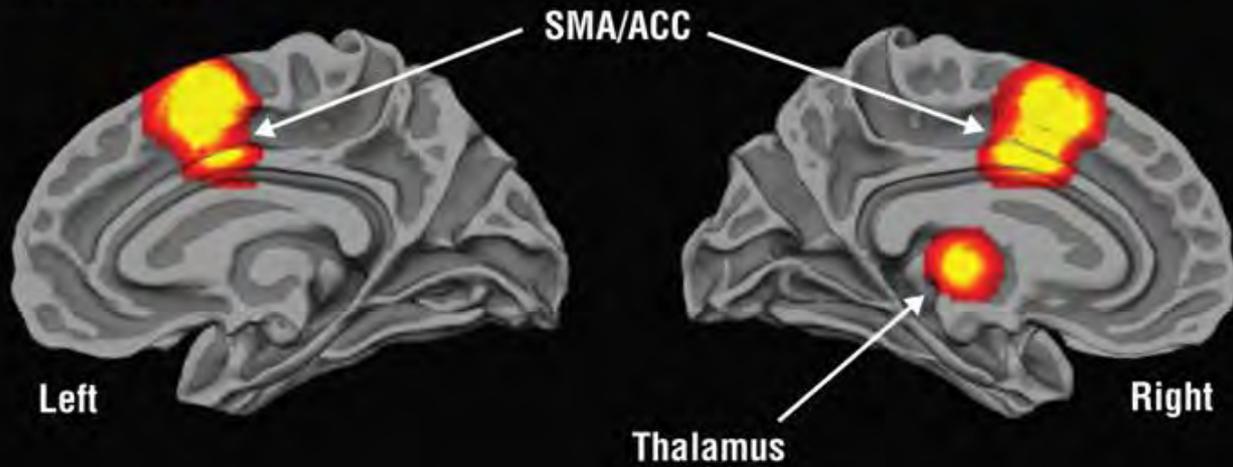
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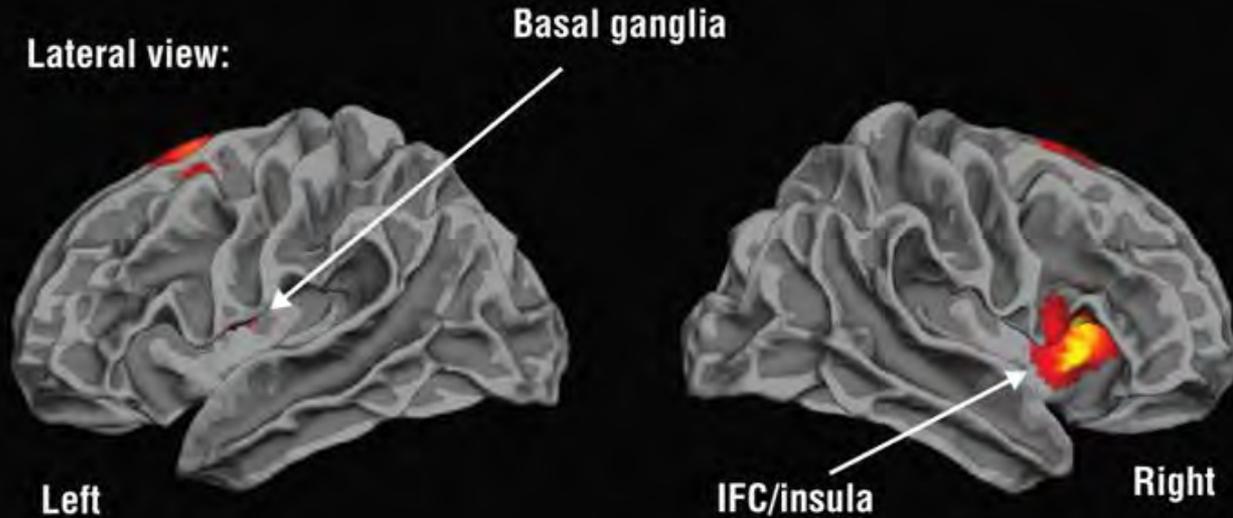
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A Inhibition

Medial view:



Lateral view:



ADHD = reduced **task-based activation** in a response inhibition network during response inhibition tasks. Implies weakened top-down signaling to control impulses. (Meta-analysis results).

 The JAMA Network

Source: Image is from Hart, Radua, et al. (2013) JAMA Psychiatry, Feb;70(2):185-98 (Fig 1). Copyright JAMA.

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SELF-REGULATION OF EMOTION AND BEHAVIOR IN ADHD

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Schematic Brain Self-regulation of emotion-behavior

Top down control
(includes pre-event goals,
values, strategies and
response inhibition and
activation)

Appetitive approach
(positive affect) can
include frustrative
anger

Aversive avoidance
(negative affect)
can include fear-
anger

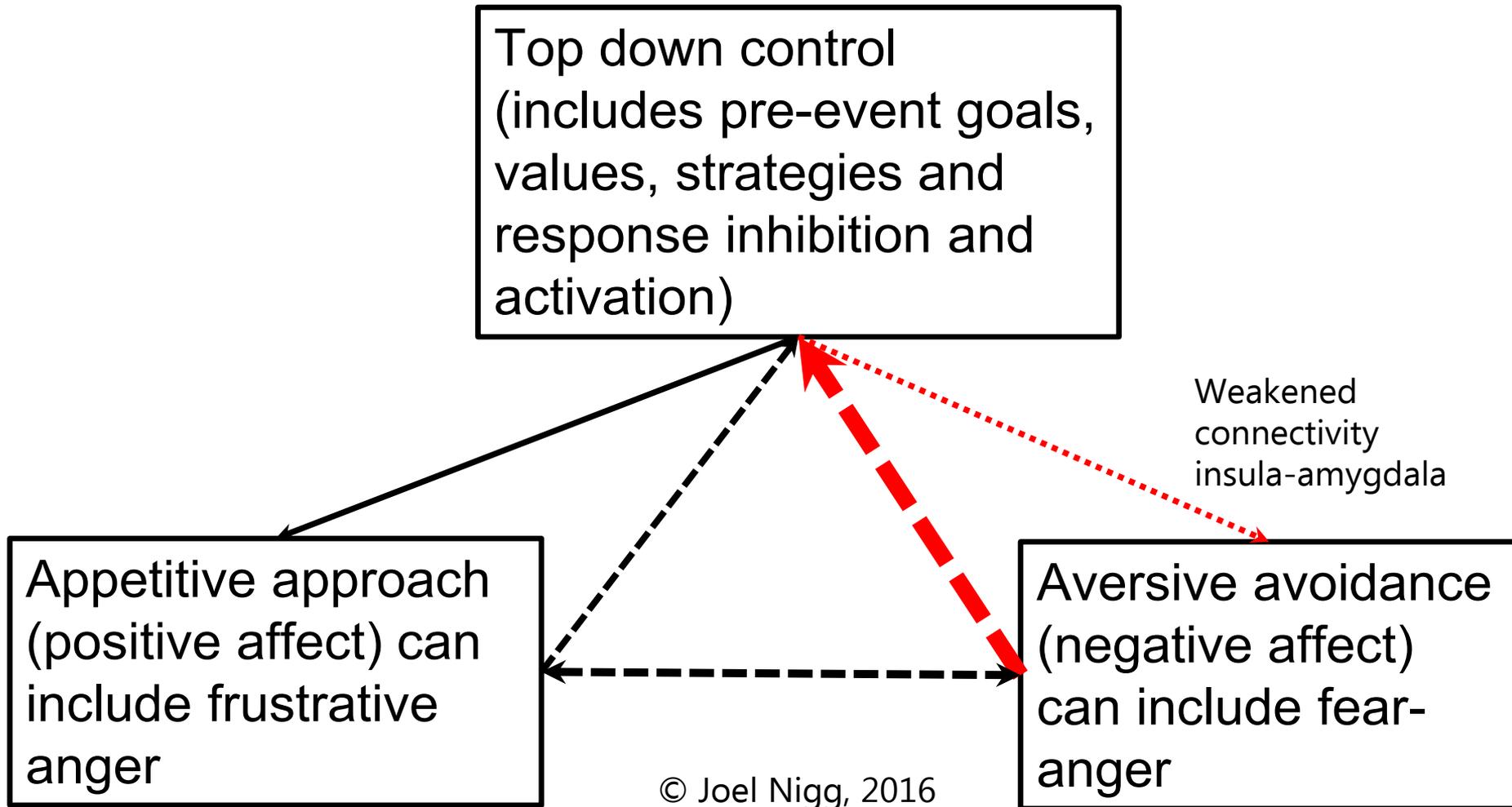
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Schematic Brain Self-regulation of emotion-behavior- One ADHD model



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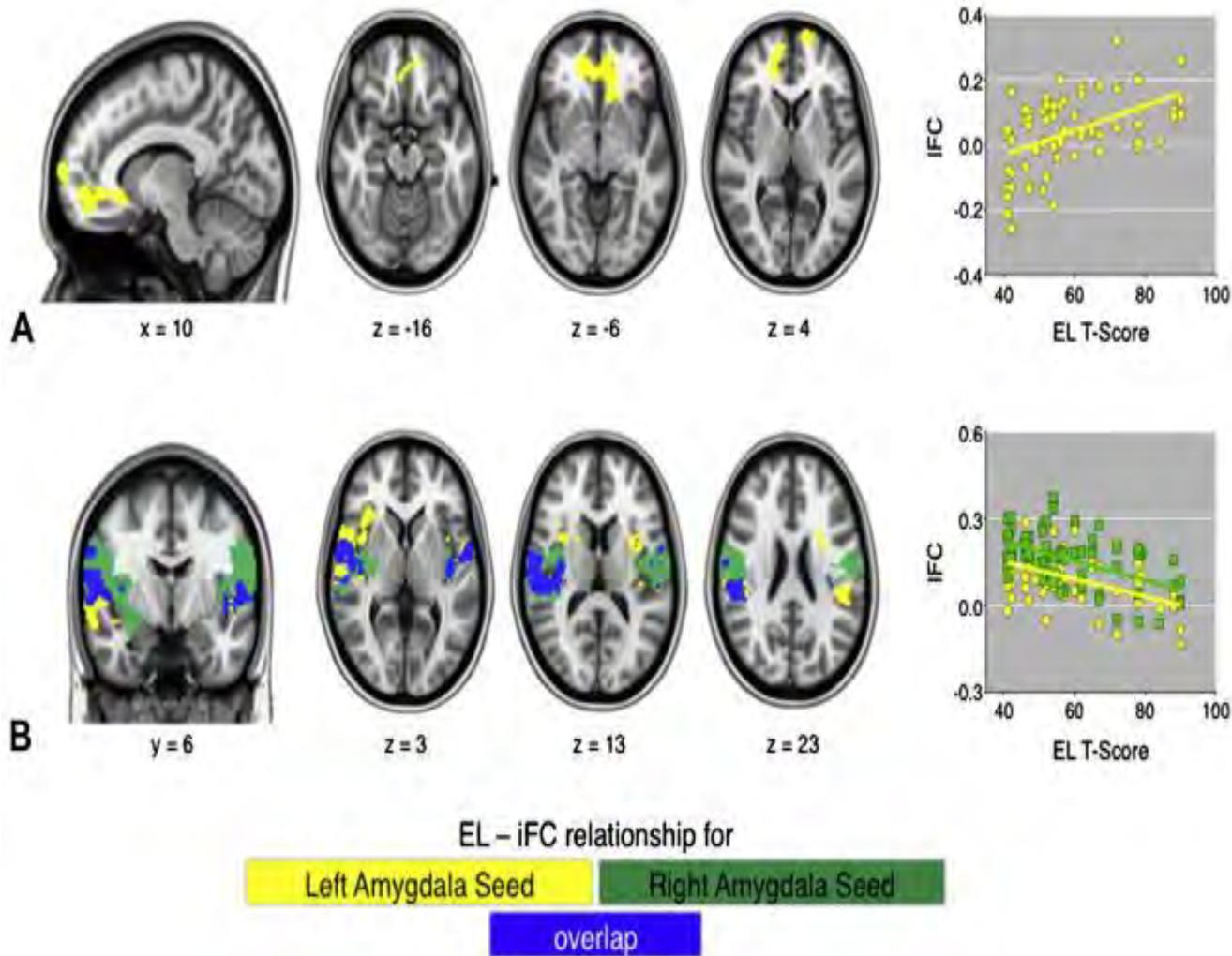
HOW DOES SCIENCE SUPPORT THIS ATTENTION EMOTION MODEL IN ADHD?

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Reduced amygdal – insula **functional** connectivity associated with more emotional lability in children with ADHD(n=63)

J Am Acad Child Adolesc Psychiatry. 2014 Mar; 53(3): 351–361.e1. Published online 2013 Dec 14. doi: [10.1016/j.jaac.2013.11.012](https://doi.org/10.1016/j.jaac.2013.11.012)/ © American Academy Child Adolescent Psychiatry

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Schematic Brain Self-regulation of emotion-behavior-A second ADHD model

Top down control
(includes pre-event goals,
values, strategies and
response inhibition and
activation)

Weakened
connectivity
PFC-striatum

Appetitive approach
(positive affect) can
include frustrative
anger

Aversive avoidance
(negative affect)
can include fear-
anger

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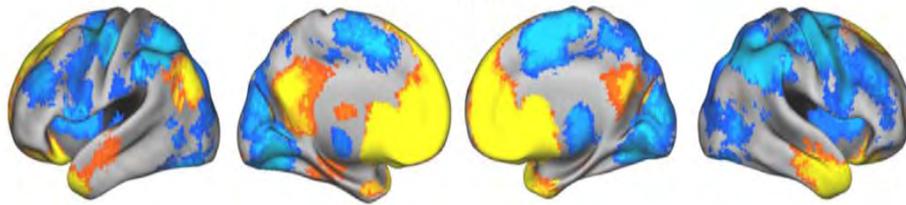
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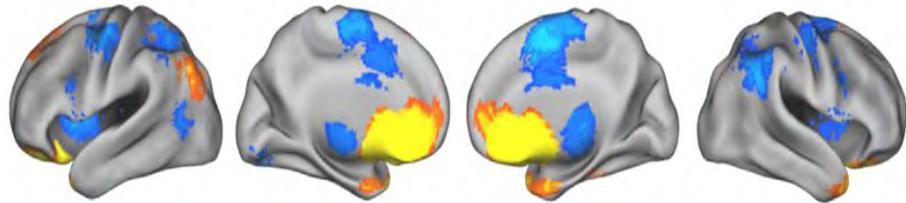
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A

All Controls



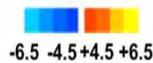
All ADHD



Left

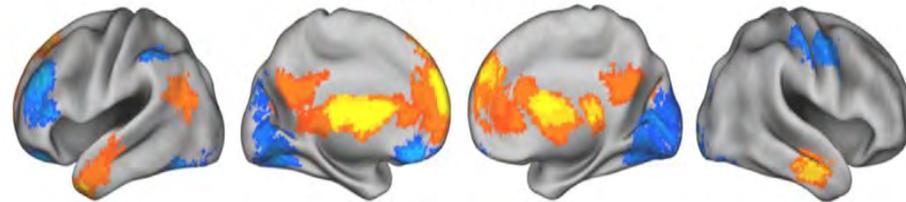
Z

Right



B

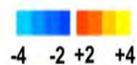
All Controls vs. All ADHD



Left

Z

Right



ADHD > Controls

Controls > ADHD

Altered development of reward circuits in ADHD associated with impulsive reward seeking (n=106). Figure shows reduced **functional** connectivity of nucleus accumbens to key regions of prefrontal cortex and other regions in ADHD

Costa Dias TG, Iyer SP, Carpenter SD, Cary RP, Wilson VB, Mitchell SH, Nigg JT, Fair DA. Dev Cogn Neurosci. 2015 Feb;11:155-74. doi: 10.1016/j.dcn.2014.12.005.

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**BUT KIDS WITH ADHD ARE
NOT ALL THE SAME...**

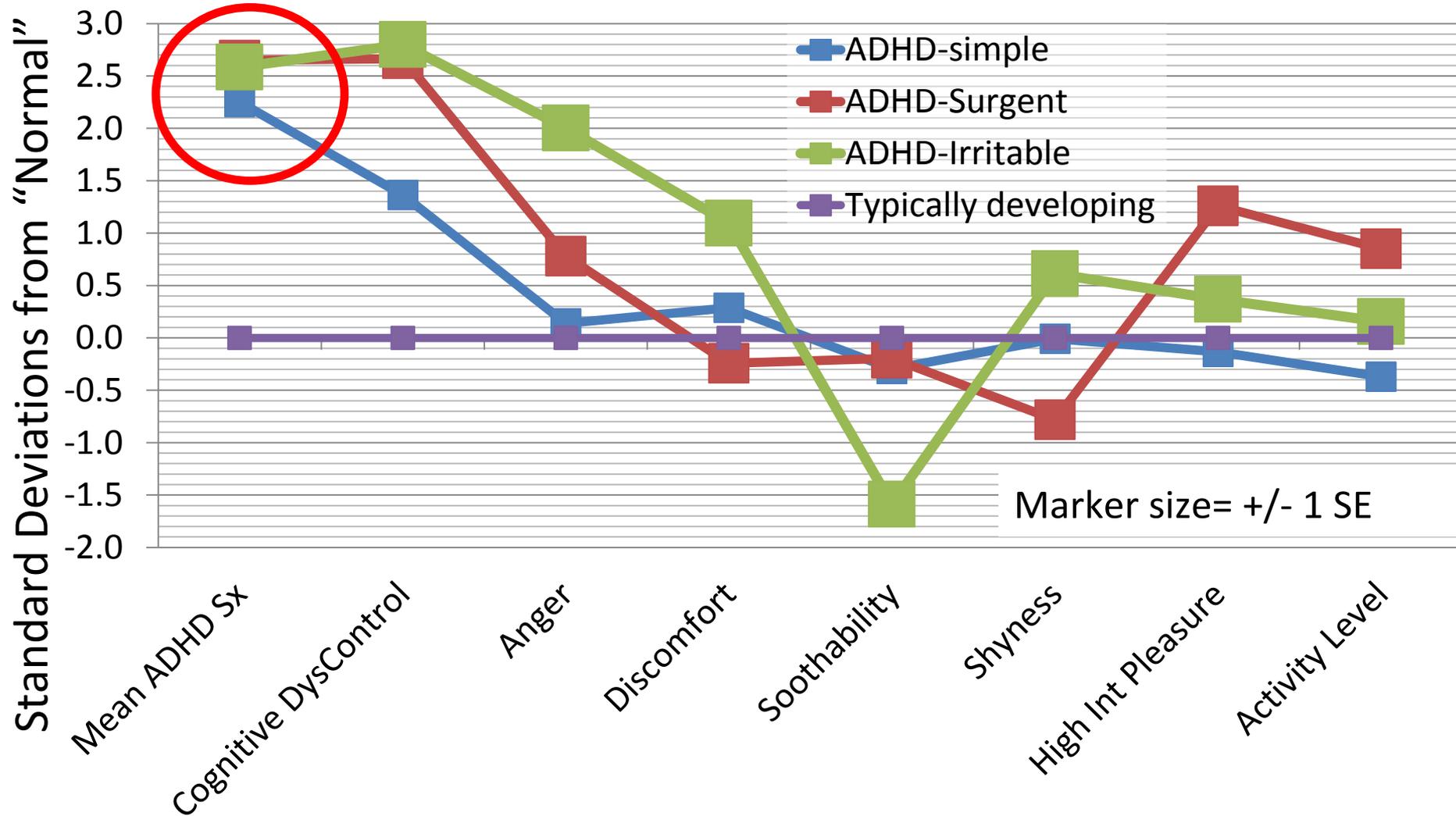
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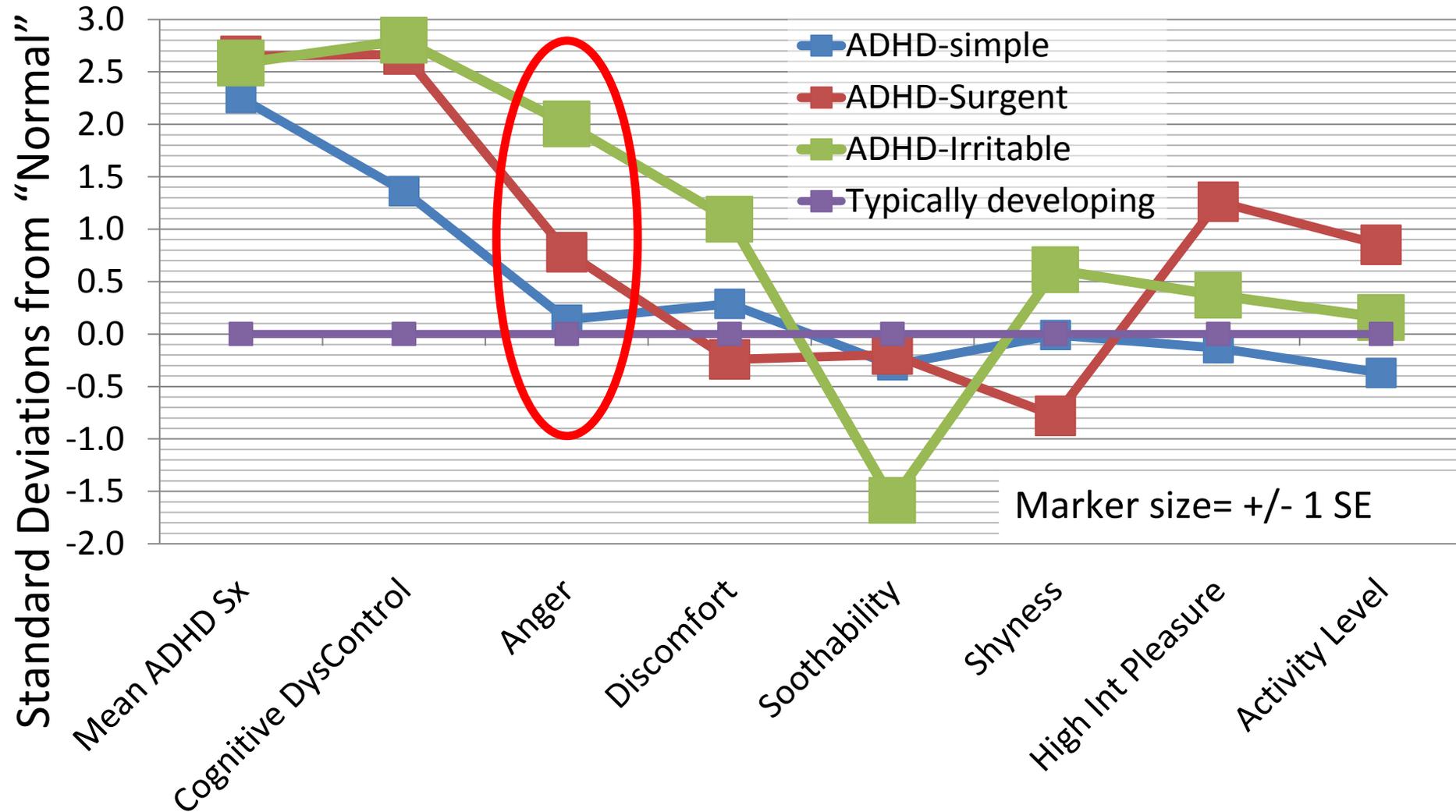
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Detailed look at subtypes of ADHD based on temperament (emotional regulation)(n=500: 310 ADHD, 190 control)

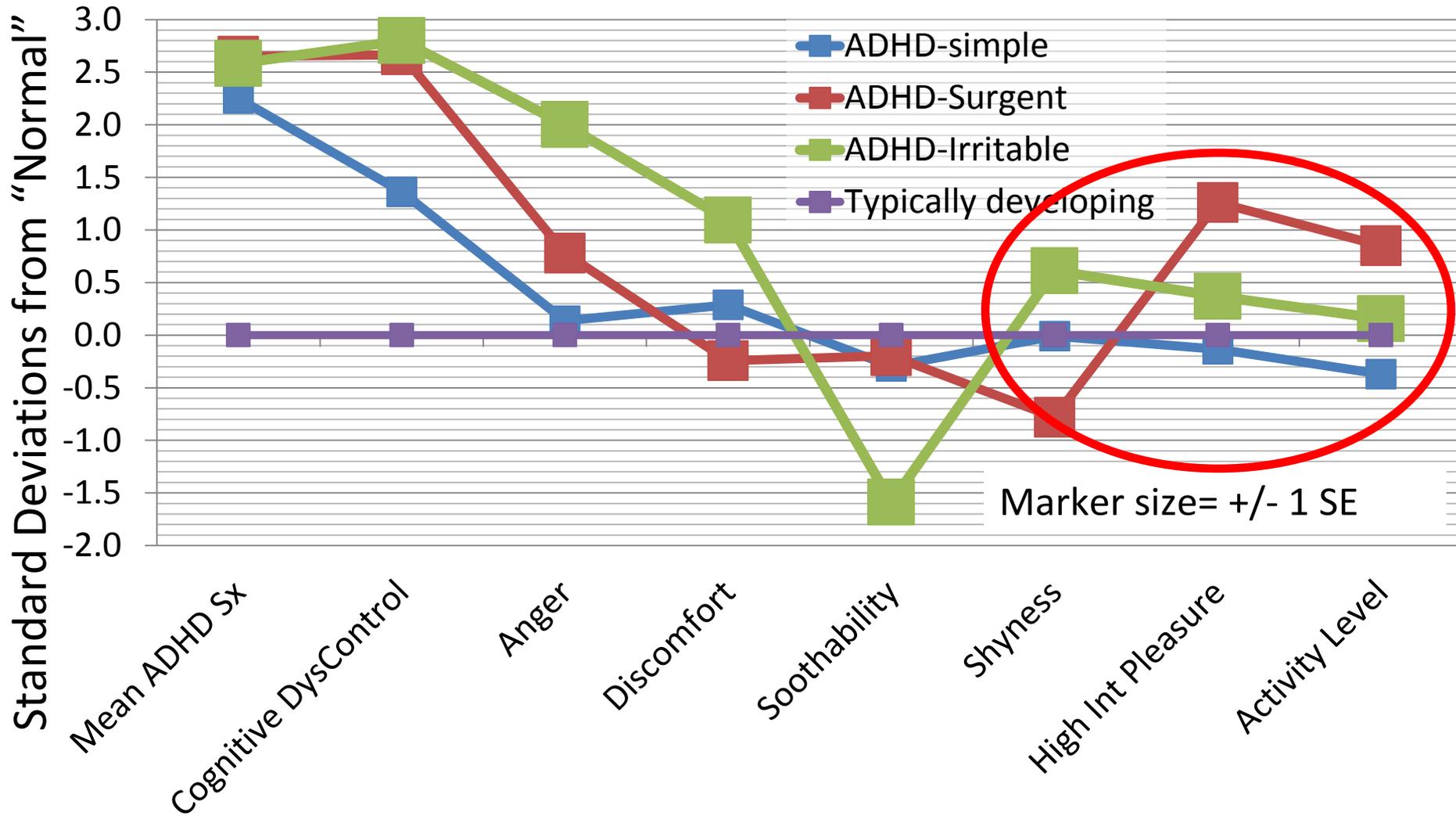


Updated and adapted from Karalunas et al, JAMA Psychiatry 2014 © JAMA network);
This figure © Joel Nigg

Detailed look at subtypes of ADHD based on temperament (emotional regulation)(n=500: 310 ADHD, 190 control)



Detailed look at subtypes of ADHD based on temperament (emotional regulation)(n=500: 310 ADHD, 190 control)



Updated and adapted from Karalunas et al, JAMA Psychiatry 2014 © JAMA network);
This figure © Joel Nigg



Summary: ADHD and Brain

- ADHD reflects under-developed connections in brain networks
- These networks handle self-regulation of attention, arousal, and emotion
- Key networks involve
 - Prefrontal cortex-parietal circuits (attention/arousal)
 - Prefrontal-subcortical circuits (emotion/behavior)
 - Dopamine, norepinephrine, glutamate, and other brain chemicals
 - Structural (white matter) and functional connections
- Children with ADHD appear to exhibit different profiles of emotional regulation and attention problems, perhaps associated with different patterns of maturation of brain networks

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Thank You

ADHD: The Brain-Behavior
Connection
Joel Nigg, Ph.D

Please enter your questions in the box to your right.



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- **Thursday, July 7th at 12pm ET**
What Summer Slide? Parent Strategies for Year-Round Learning with Ann Dolin, M.Ed.
- **Thursday, July 14th at 1pm ET**
How to Start (and End) the School Year Organized with Susan Lasky, M.A.

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ADDConnect

ADDitude's online community for attention deficit support and solutions where you can join our ongoing ADHD discussion groups:

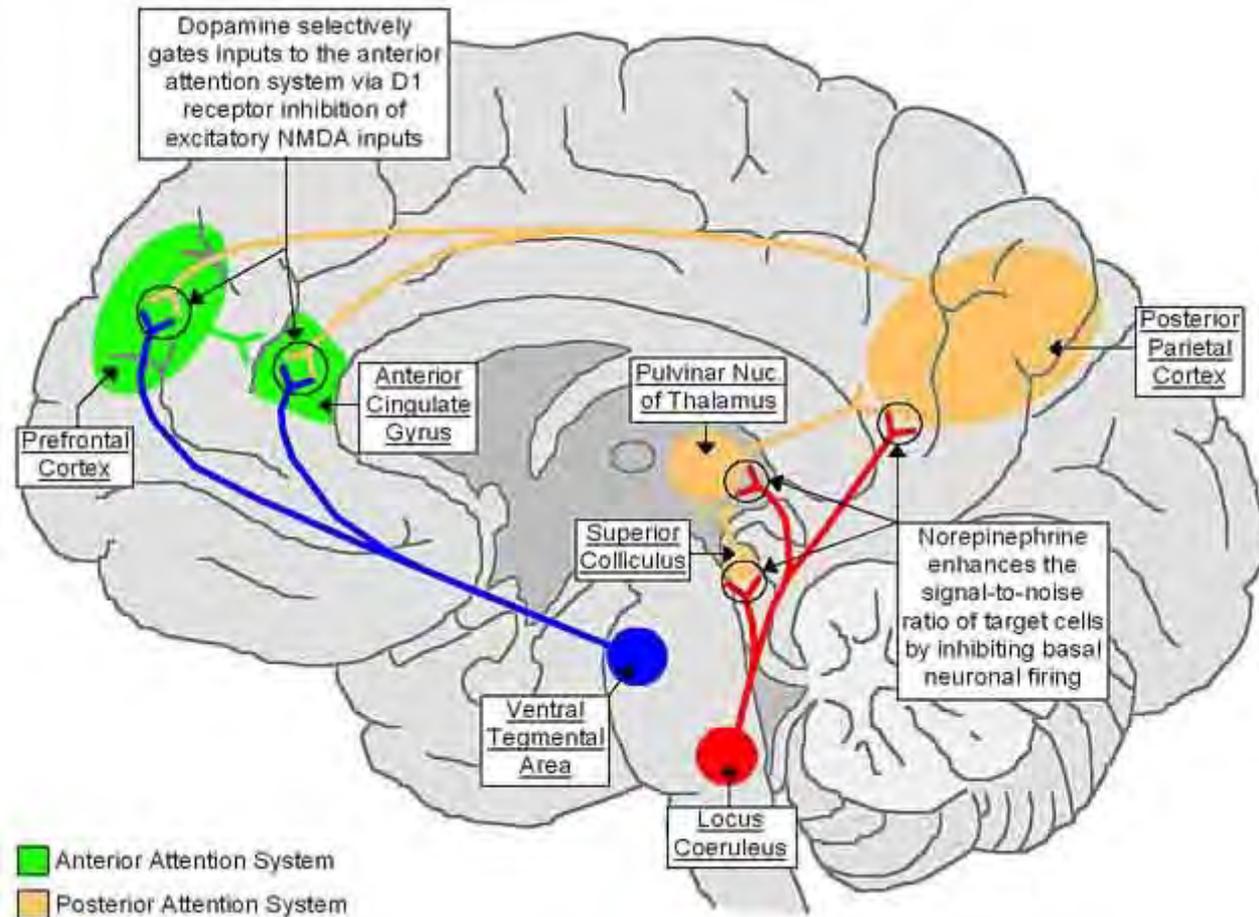
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Neurotransmitter function view of ADHD problems in arousal and attentional control



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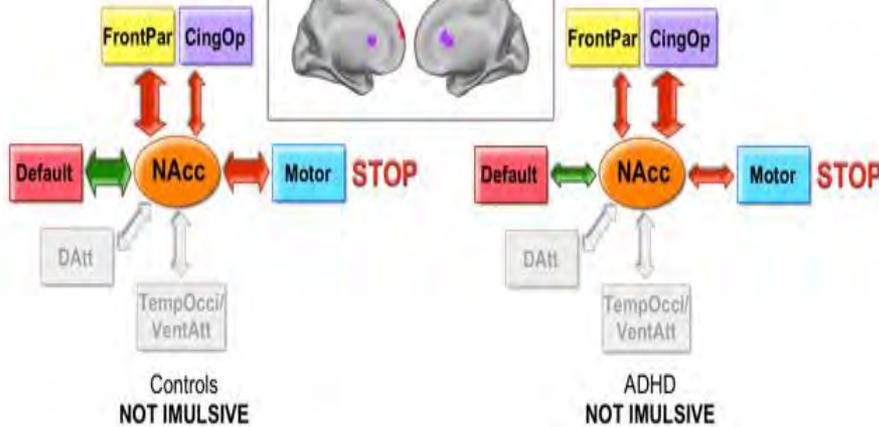
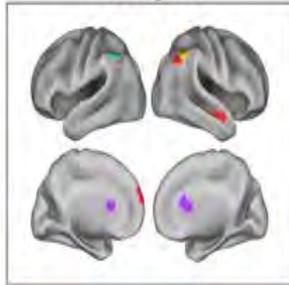
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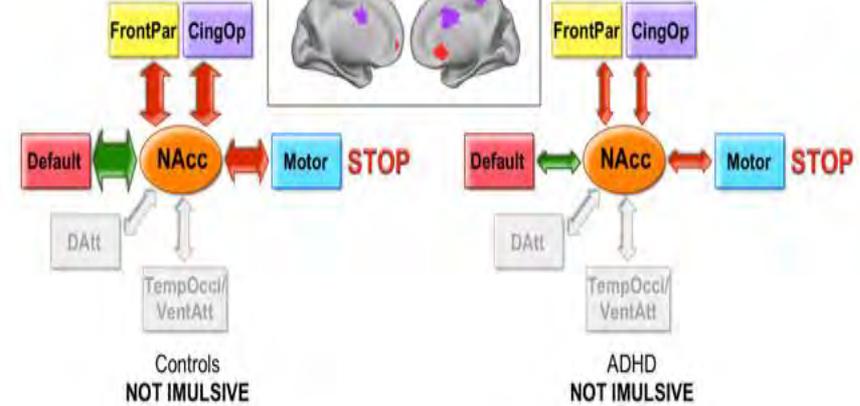
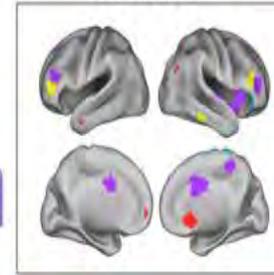
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Subgroups of ADHD within reward circuits (n=106)

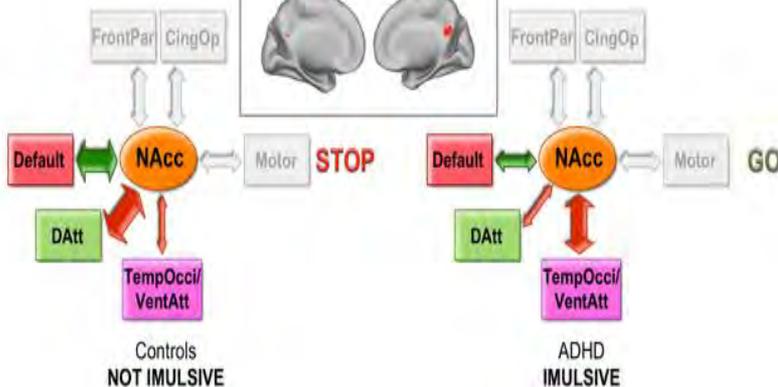
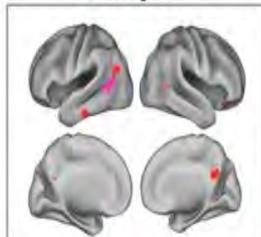
Group B



Group C



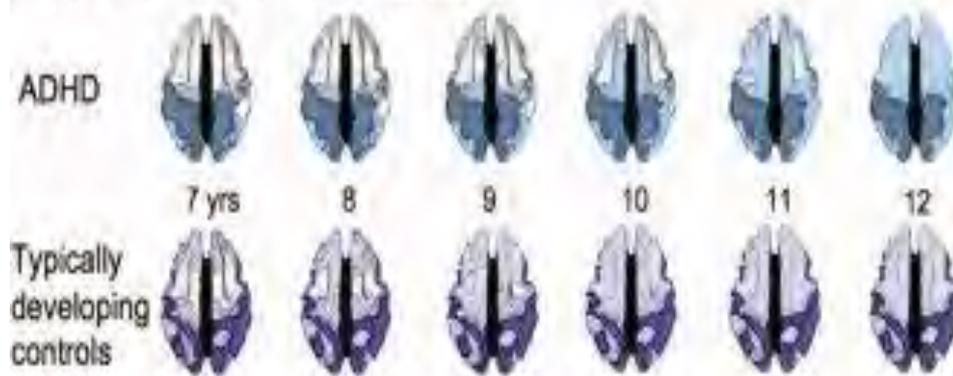
Group A



Costa Dias TG, Iyer SP, Carpenter SD, Cary RP, Wilson VB, Mitchell SH, **Nigg** JT, Fair DA. Dev Cogn Neurosci. 2015 Feb;11:155-74. doi: 10.1016/j.dcn.2014.12.005.

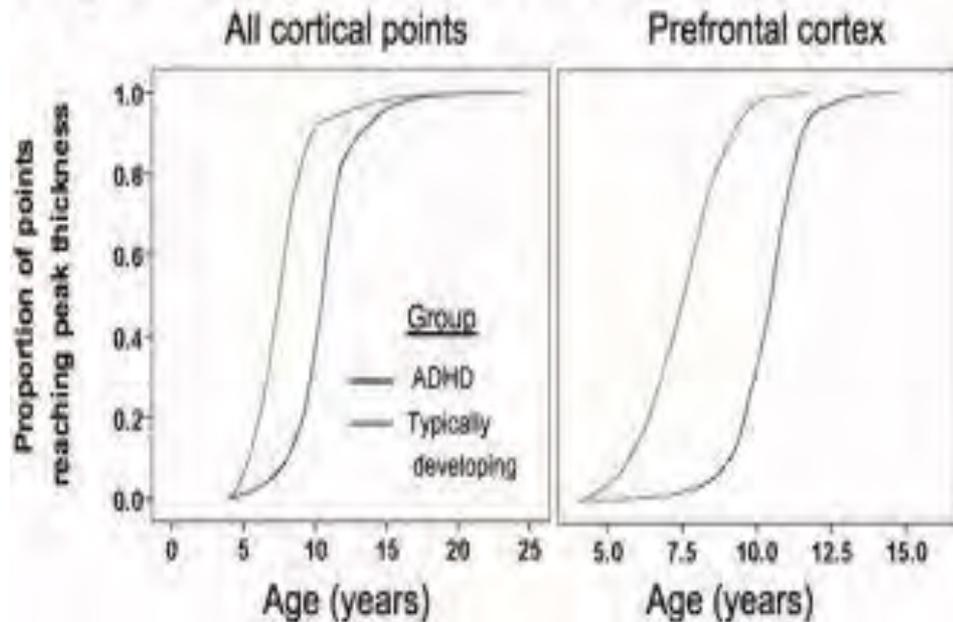
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A. Spread of cortical maturation



Slower maturation of cortical thickness in ADHD by about 2-3 years

B. Age of attaining peak cortical thickness

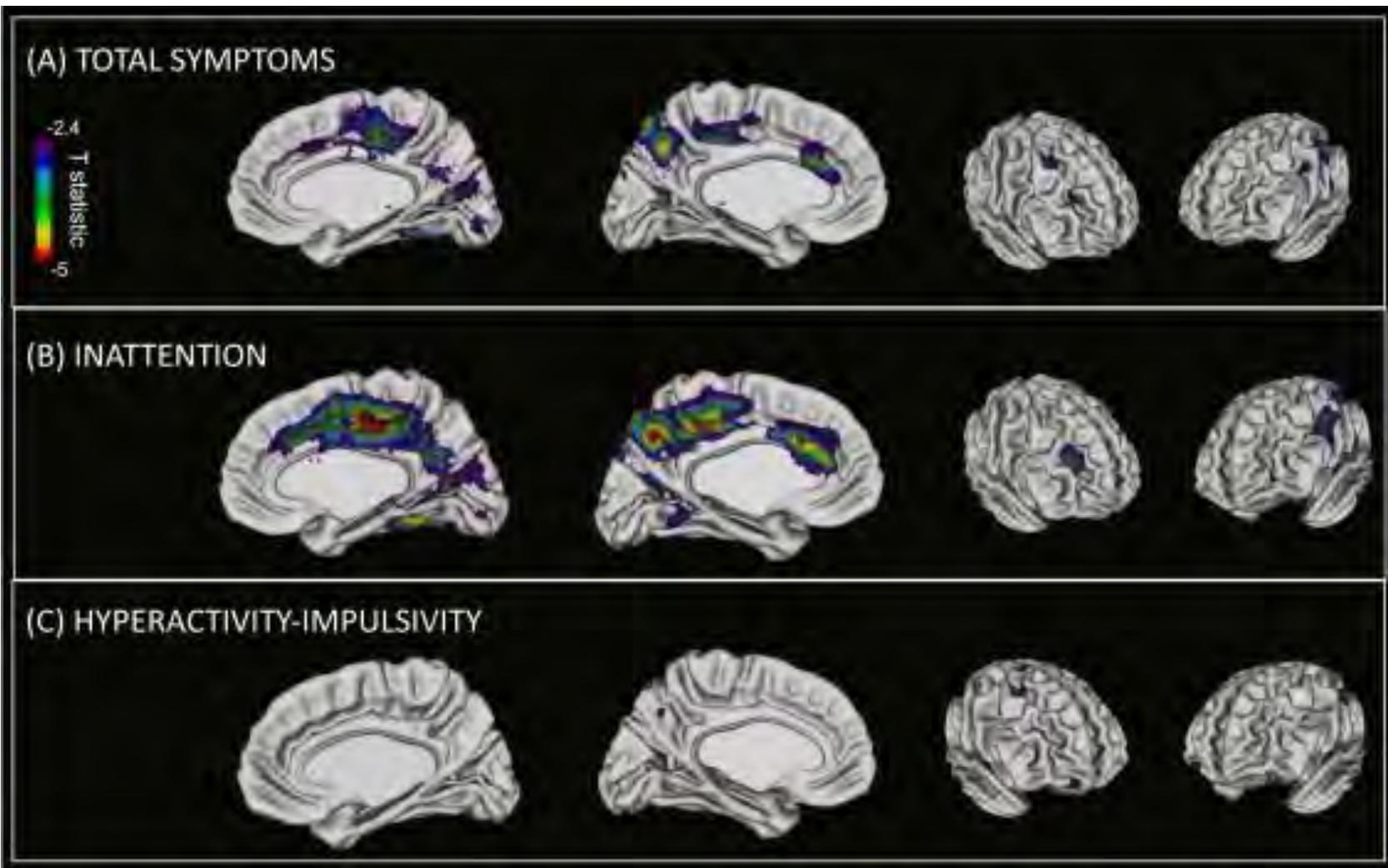


Shaw et al; Proceedings of the National Academies of Science, 2007 Dec 4;104(49):19649-54.
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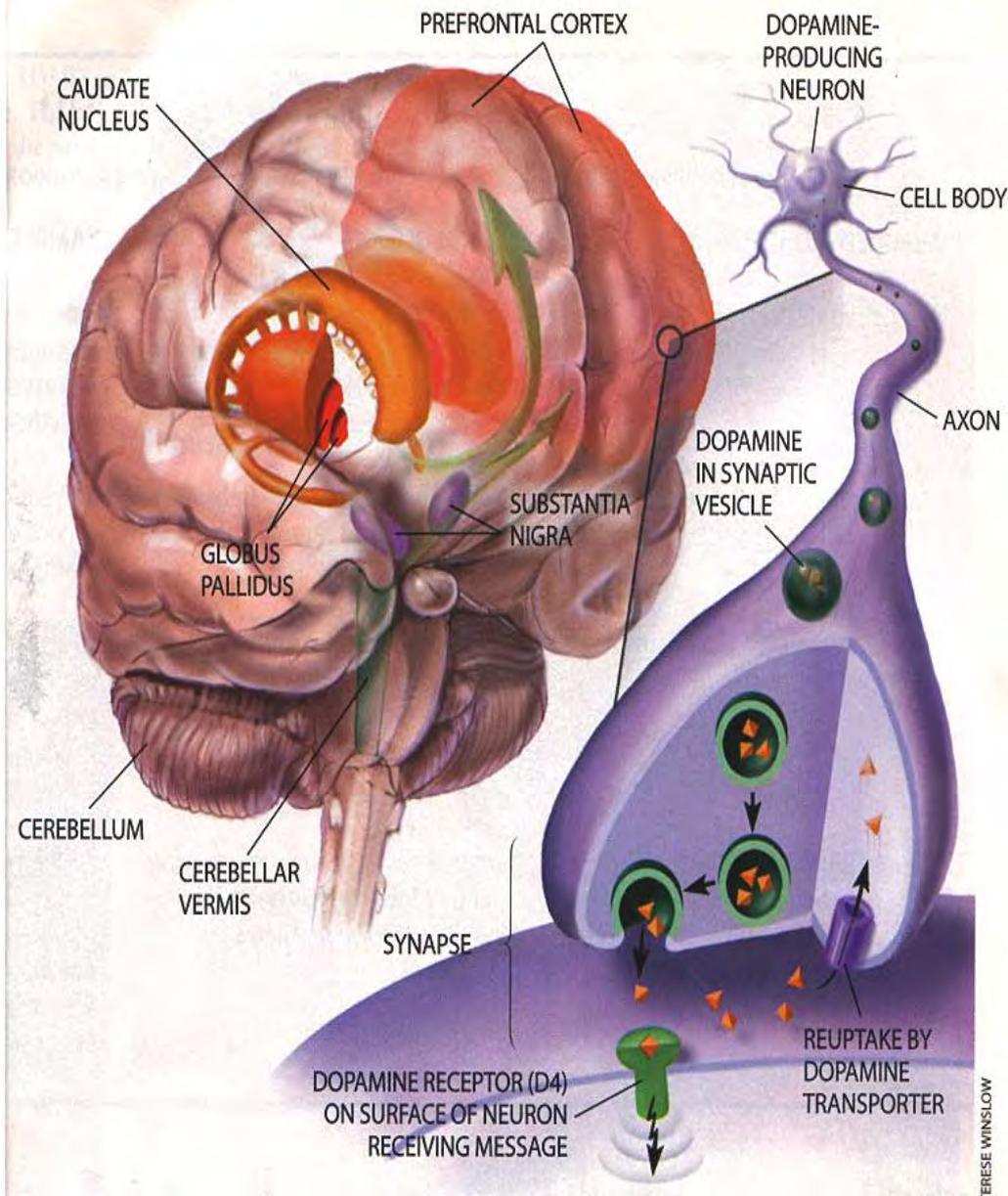


From Shaw, Malek, et al (2013). Trajectories of Cerebral Cortical Development in Childhood and Adolescence and Adult Attention-Deficit/Hyperactivity Disorder *Biological Psychiatry*, Volume 74, Issue 8, 2013, 599 – 606 A) Regions where the total number of attention-deficit/hyperactivity disorder symptoms in adulthood are significantly associated ($p < .05$, adjusted for multiple comparisons) with the cortical trajectories from childhood into adulthood. The association is stronger for inattentive (B) than hyperactive-impulsive symptoms (C). © Society for Biological Psychiatry

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The Classic Understanding of ADHD Neural Involvement

Insufficient synaptic DA reduces salience and significance of signals

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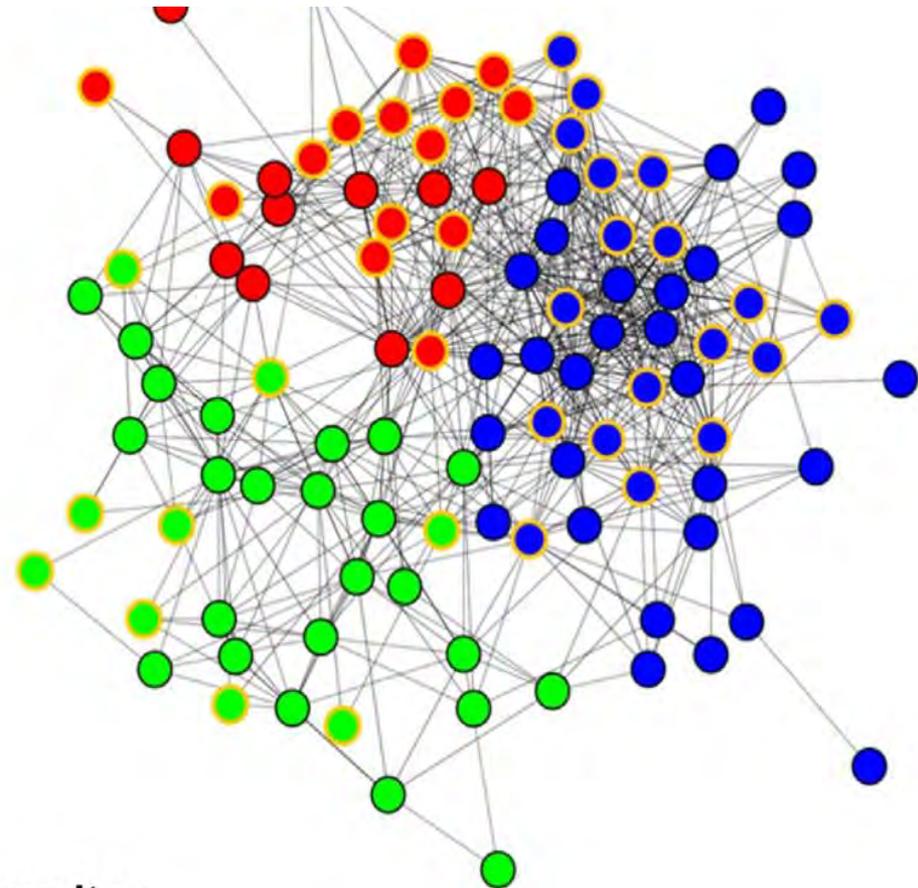
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Graph of Community organization analysis showing different groups based on connectivity to the nucleus accumbens reward-related circuits in ADHD

[Costa-Dias et al \(2015\)](#)
[Dev Cogn Neurosci.](#)
[Author manuscript;](#)
[available in PMC 2016](#)
[Feb 1.](#)Published in final
edited form as:
Dev Cogn Neurosci.
2015 Feb; 11: 155–174.
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Community:

-  Subgroup A
-  Subgroup B
-  Subgroup C

Group:

-  Control
-  ADHD

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