The Brain-Behavior Connection

In Children with ADHD

https://youtu.be/4z9ZM_q14pY
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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
HOW DOES THE BRAIN WORK IN CONCEPT?
Neuron and Network Concept

Cell body ("gray matter")

Myelin ("white matter")

Axons

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Critical circuits and networks ADHD Brain

- Frontal cortex
- Parietal cortex
- Supplementary motor cortex
- Accumbens nucleus
- Thalamus
- Basal ganglia
- Cerebellum

- Fronto-cerebellar network
- Fronto-striatal network
- Executive function network
- Attentional network

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

Bottom up capture by novelty, conflicting signals, automatic filtering (parietal cortex), or my memories/thoughts

Bottom up capture by emotional signal, outward or inward (limbic-hippocampal)

Top down biasing via goals, focused attention, suppressing (frontal cortex)

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

Bottom up capture by novelty, conflicting signals, automatic filtering (parietal cortex), or my memories/thoughts

Bottom up capture by emotional signal, outward or inward (limbic-hippocampal)

Top down biasing via goals, focused attention, suppressing (frontal cortex)

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HOW DOES SCIENCE SUPPORT THIS MODEL IN ADHD?

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

Source: Image is from Hart, Radua, et al. (2013) JAMA Psychiatry, Feb;70(2):185-98 (Fig 1). Copyright JAMA.
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
An alternative model of attentional and impulsivity self-regulation in the brain: ADHD Model of weakened ACC/insula-amygdala connectivity

Bottom up capture by novelty, conflicting signals, automatic filtering (parietal cortex), or my memories/thoughts

Bottom up capture by emotional signal, outward or inward (limbic-hippocampal)

Top down biasing via goals, focused attention, suppressing (frontal cortex)

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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).

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

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

Weakened connectivity insula-amygdala

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HOW DOES SCIENCE SUPPORT THIS ATTENTION EMOTION MODEL IN ADHD?
Reduced amygdal – insula functional connectivity associated with more emotional lability in children with ADHD (n=63)

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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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.

BUT KIDS WITH ADHD ARE NOT ALL THE SAME...
Detailed look at subtypes of ADHD based on temperament (emotional regulation) (n=500: 310 ADHD, 190 control)

- ADHD-simple
- ADHD-Surgent
- ADHD-Irritable
- Typically developing

Standard Deviations from “Normal”

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)

-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

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

This figure © Joel Nigg

Updated and adapted from Karalunas et al, JAMA Psychiatry 2014 © JAMA network)
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
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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To continue the conversation, we invite you to join us on ADDConnect

ADDitude’s online community for attention deficit support and solutions where you can join our ongoing ADHD discussion groups: www.addconnect.com.
Neurotransmitter function view of ADHD problems in arousal and attentional control

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Subgroups of ADHD within reward circuits (n=106)

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

Shaw et al; Proceedings of the National Academies of Science, 2007 Dec 4;104(49):19649-54. © PNAS
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
The Classic Understanding of ADHD Neural Involvement

Insufficient synaptic DA reduces salience and significance of signals

Graphic is copyright Scientific American; Sept. 1998, p. 47
Graph of Community organization analysis showing different groups based on connectivity to the nucleus accumbens reward-related circuits in ADHD