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Neurocognitive Deficits in ADHD

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Core Symptoms

- Hyperactivity
- Impulsivity
- Inattention

Neurocognitive Theories

- Most of neurocognitive theories of ADHD have highlighted the role of:
- executive functions,
- attention,
- Working memory
- behavioral inhibition,
- and delay aversion

Executive Functions

- Executive functions are broadly defined as a collection of correlated but highly separable higher order supervisory control processes involved in the flexible production
- and regulation of complex goal-directed problem-solving thoughts and actions, particularly in nonroutine situations.

Executive Functions

- EF comprises higher-order self-regulatory functions, including
- the ability to inhibit,
- plan,
- organize,
- problem-solve,
- use working memory,
- shift attentional set, and maintain attentional set for future goals (Seidman, 2006).

Executive Functions

- On the basis of a recent review, the core EFs include inhibition, working memory, and cognitive flexibility [also called set shifting *(Diamond A. 2013)*
- higher-order EFs, such as reasoning, problem solving, and planning, are built on the foundation of the three core Efs *(Diamond A. 2013)*

Executive Functions

- the physiological substrates underlying EF include a complex network involving:
- prefrontal, parietal, singular, insular, premotor cortices,
- and subcortical (e.g., basal ganglia) regions *(Weyandt, 2005).*

Behavioral Inhibition

- Deficits in behavioral inhibition or impulse control are central to ADHD *(Barkley, 1997)*.
- Children with ADHD demonstrate impairment in three interrelated inhibitory processes:
- inhibition of the prepotent response to an event,
- stopping of an ongoing response,
- and interference control

Behavioral Inhibition

- Barkley's (1997) model proposed that impairment in this primary domain is linked to secondary impairment of four key EFs that rely heavily on inhibition :
- working memory,
- self-regulation of affect-motivation-arousal,
- internalization of speech,
- and reconstitution (behavioral analysis and synthesis) (Mohlman 2015).

Behavioral Inhibition

The main deficit in ADHD children can be reduced to a single deficiency in the capacity to delay responding to signal, event, or stimulus (Barkley, 1994).

Behavioral Inhibition

This impairment in delayed responding creates a hypersensitivity to immediate signals or events.

This hypersensitivity leads to :

Hyperactivity

Inattention

Behavioral Inhibition

- Neuropsychological tests demonstrating behavioral inhibition include:
- go-no-go,
- stop-signal,
- Stroop (e.g., SCWT, Stroop, 1935; Golden, 1978),
- and CPT paradigms (e.g., Continuous Performance Test-II, *(Conners, 2004)*

Behavioral Inhibition

- Functional imaging studies provide evidence to suggest that inhibitory-based deficits are linked to hypoactivation in prefrontal cortex *(Rubia et al., 2005)*
- and the dorsal striatum *(Vaidya et al., 2005)*.

Working memory

- Working memory is also frequently impacted in ADHD
- Working memory refers to the ability to actively maintain and manipulate task-relevant information over a limited period of time.

Working memory

- According to Barkley, children with ADHD experience deficiencies in working memory and its subfunctions, including
- difficulty holding past information in mind (hindsight) for the formulation of future plans (forethought),
- temporal disorganization of retrospective recall,
- a compromised sense of time,
- and a tendency to be more influenced by temporally proximal events and consequences than those more distal in time (Mohlman 2015).

Attention

- Evidence suggests that ADHD is associated with impairment in:
- selective attention (the ability to ignore distracting information when performing a perceptual act on relevant information),
- sustained attention (the ability to sustain attention to relevant information over a relatively long period of time while withholding responses to irrelevant items),

Attention

- and the orienting of attention (the ability to benefit from a cue that automatically attracts attention to a specified location,
- or disengage and reorient to a different location (Tsal, Shalev, & Mevorach, 2005, Weissman, Chu, Reddy, & Mohlman, 2012).

Attention

- Neurophysiological and anatomical findings support the notion of multiple attentional deficits in ADHD, indicating abnormalities
- in the right frontal lobes (sustained attention),
- right parietal lobes (orienting of attention),
- and corpus callosum (orienting of attention; Tsal et al., 2005).

Delay Aversion

- Delay Aversion refers to a difficulty delaying gratification and a tendency to "discount delay" by selecting immediate lesser rewards over delayed greater ones.
- Sonuga-Barke (2003) proposes that two pathways exist that each contribute to the disorder,

Delay Aversion

- the first being executive dysfunction,
- and the second being deficits in reward processing or DA, making it difficult for ADHD individuals to put off a smaller immediate reward in favor of a larger reward later.

Delay Aversion

- One of the most consistent findings in this domain is that ADHD individuals respond differently to delayed reward *(e.g., Marco et al., 2009)*.
- This may be due to altered signaling of future rewards
- and higher rate of decay of the value of those rewards as suggested in models by Sagvolden et al. *(2005)*.

Delay Aversion

- Altered motivational and reward-related processes are also implicated in ADHD.
- Functional magnetic resonance imaging (fMRI) studies implicate hypoactivation in the ventral striatum/nucleus accumbens
- and the orbito-frontal cortex in response to cues of anticipated rewards *(e.g., Plichta et al., 2009).*

Brain Structure and Function in ADHD

- ADHD is probably a disorder in the prefrontal lobes and its pathways with the caudate nucleus,
- striatum,
- and other limbic system structures (Giedd, 1993).

Brain Structure and Function in ADHD

- The ability of ***Response Inhibition*** is believed to be mediated by the Frontal Lobes
- and their rich connections to the striatum (*Barkley*).

Brain Structure and Function in ADHD

- A meta-analysis shows hypoactivation in the frontoparietal
- and ventral attention networks in children with ADHD,
- areas which control goal-directed executive processes and decision making.

Brain Structure and Function in ADHD

- Hart and colleagues found that right dorsolateral prefrontal cortex activation was reduced in medication-naive patients,
- but normal in long-term stimulant-medicated patients

Brain Structure and Function in ADHD

- MRI studies suggest that there are structural abnormalities in the brains of children with ADHD, including differences
- in the frontostriatal areas,
- temporoparietal lobes,
- cerebellum, basal ganglia, corpus callosum,
- amygdala, hippocampus, and thalamus.

Brain Structure and Function in ADHD

- meta-analysis of voxel-based morphometric (VBM) studies by Nakao and colleagues of children and adults with ADHD found
- global reductions in gray matter volumes, especially the dorsolateral prefrontal cortex
- and right lentiform nucleus extending to the caudate nucleus,

Brain Structure and Function in ADHD

- a meta-analysis, showed a significant difference in volume between ADHD and controls in different regions of cerebellum (Valera et al. 2007):
- posterior inferior vermis of the cerebellum,
- cerebellar vermis, splenium,
- total cerebral volume,
- right cerebellum, left cerebellum, and caudate.

Brain Structure and Function in ADHD

- Most of the candidate networks have focused on prefrontal–striatal–cerebellar circuits,
- although other posterior regions are also being proposed

Brain Structure and Function in ADHD

- These areas were demonstrated to normalize with age as well as with stimulant medication treatment.
- Developmentally, children with ADHD have a 3- to 5-year delay in cortical thickness maturation,
- particularly in the frontal and temporal brain regions.

Brain Structure and Function in ADHD

- Some researchers have reported thinning, specifically within the dorsolateral prefrontal cortex,
- anterior cingulate,
- and inferior parietal lobe, to be linked to the persistence of ADHD symptoms into adulthood (Makris et al., 2007),
- whereas remission has been linked to thicker cortex in medial occipital, parahippocampal, insular, and prefrontal regions (Proal et al., 2011)

Brain Structure and Function in ADHD

- growth of the anterior cingulate,
- striatum,
- and medial temporal cortex has been associated with improved response inhibition in school-age children with ADHD (McAlonan et al., 2009),

Brain Structure and Function in ADHD

- these studies indicate that normalization of brain anomalies or delays may be associated with disorder remission,
- whereas lack of normal maturation is predictive of persistence of ADHD throughout development (Halperin & Healey, 2011).

Brain Structure and Function in ADHD

- It is thus conceivable that therapies targeting core neurodevelopmental processes via enrichment early in life could potentially alter the trajectory of brain development and,
- consequently, the course of ADHD (Halperin, Bedard, & Curchack-Lichtin, 2012).

Summary

- Abnormalities in the basal ganglia, prefrontal structures, and the corpus callosum have been the most consistently reported findings across studies.
- functional MRIand magnetoencephalography measurements have also shown differences in neural activity during the execution of neuropsychological tasks and during rest, in widespread regions of the brain *(Saenz 2018)*

Emotion Processing in ADHD

Emotion Regulation

- one of the most challenging aspect of ADHD is the heightened emotional lability (EL) (Barkley 1997)
- Emotional lability indicates a tendency for intense, or strong, emotional reactions (Conners 2008; Maedgen & Carlson 2000; Sobanski et al 2010)
- and has been described in youths with ADHD in both the clinical and research literature (Barkley & Fischer 2010)

Emotion Regulation

- Findings from several studies of school-aged children have shown that poor emotion regulation is related to ADHD (e.g.,Anastopoulosetal. 2011; Maedgen and Carlson 2000; Walcott and Landau 2004).
- In addition, these deficits have been shown to be at least partly independent of deficits in other neuropsychological functions in relation to ADHD (e.g., Berlin, Bohlin, Nyberg, and Janols2004; Blaskey, Harris, and Nigg 2007; Sjöwall et al. 2013).

Emotion Regulation

- There are two main, competing hypotheses:
- The first maintains that ER in ADHD patients stems primarily from impairments in cognitive control (Barkley 1997).
- The competing hypothesis maintains that it is emotional processing itself that is dysfunctional with emotional stimuli generating strong emotional responses in youth with ADHD (Sonuga-Barke et al 1992, Posner 2012)

Emotion Regulation

- To confirm the second hypothesis, Posner (2012) conducted a study examining adolescents with ADHD as compared with controls during the emotional and cognitive Stroop tasks, and found that:
- unmedicated ADHD participants demonstrated increased reactivity in the medial PFC relative to healthy controls in the emotional processing task

Emotion Regulation

- this increased reactivity of the mPFC in the adolescents with ADHD was specific to emotional processing
- and was detected even after controlling for differences in cognitive control

Emotion Regulation

- dysfunctional emotional processing in ADHD seems to be underpinned by neural alterations independent from those associated with impaired cognitive control
- stimulants reduced the reactivity of the mPFC toward levels similar to those of healthy controls
- It can be concluded that the mPFC in ADHD youth may augment, or facilitate, affective responses *(Posner 2012)* .

Emotion Regulation

- Neural mechanisms in emotion processing:
- It is useful to distinguish between regions mediating bottom-up responses to emotional stimuli—specifically the amygdala, ventral striatum, and orbitofrontal cortex—
- and top-down cortical regions controlling the allocation of attentional resources in emotionally arousing contexts

Emotion Regulation

- Most studies find amygdala hyperactivation in ADHD, during both the subliminal perception of fearful expressions and while subjects rated their fear of neutral faces
- Amygdala hyperactivation has also been reported in ADHD during the processing of delayed rewards, consistent with the delay aversion found in some behavioral studies *(Ströhle 2008, Stoy 2011)*.

Emotion Regulation

- The orbitofrontal cortex, which has rich interconnections with the amygdala, the thalamus, and multiple cortical regions, is pivotal in emotion regulation and reward representations *(Phillips ML 2008)*
- Some data suggest orbitofrontal anatomic anomalies (Overmeyer S, 2001)

Emotion Regulation

- and abnormal activation during the anticipation and receipt of rewards in ADHD.
- There is also decreased connectivity between the amygdala and the orbitofrontal cortex, *(Plessen KJ 2006, Shaw 2014 for review).*

Emotion Regulation

- The ventral striatum is another important hub in the bottom-up circuitry, partly by virtue of its role in mediating positive affect and reward processing *(Knutson 2001)*.
- Functional neuroimaging studies find reduced ventral striatum responsiveness in ADHD during the anticipation (and receipt) of rewards, thus contributing to aversion to delay

Emotion Regulation

- two independent studies using the emotional Stroop task *(Passarotti 2010, Posner 2012)* found hypoactivation in ADHD in the right medial and ventrolateral prefrontal cortex while processing negative distractors
- but hyperactivation in the left medial prefrontal cortex while processing positive distractors.

Emotion Regulation

- Recent studies indicated that children with ADHD showed a decreased functional connectivity between the insula and amygdala interacting with emotional regulation *(Hulvershorn LA 2014; Yu X, 2016)*.

Emotion Regulation

- In summary, emotion dysregulation in ADHD implicates dysfunction in the amygdala,
- ventral striatum,
- and orbitofrontal cortex,
- which could be regarded as the bottom-up contributor.

Emotion Regulation

- Regions at the interface of cognition and emotion (the medial and ventrolateral prefrontal cortex)
- may underpin the abnormal allocation of attention to emotional stimuli
- and could thus be regarded as the major top-down contributor to emotion dysregulation in ADHD (Shaw 2014 for review)

Emotion Regulation

- It is predicted that dysfunction at the cortical nexus between cognition and emotion (the medial and ventrolateral prefrontal cortex) is strongly associated with symptoms of both ADHD and emotion dysregulation *(Shaw 2014 for review).*

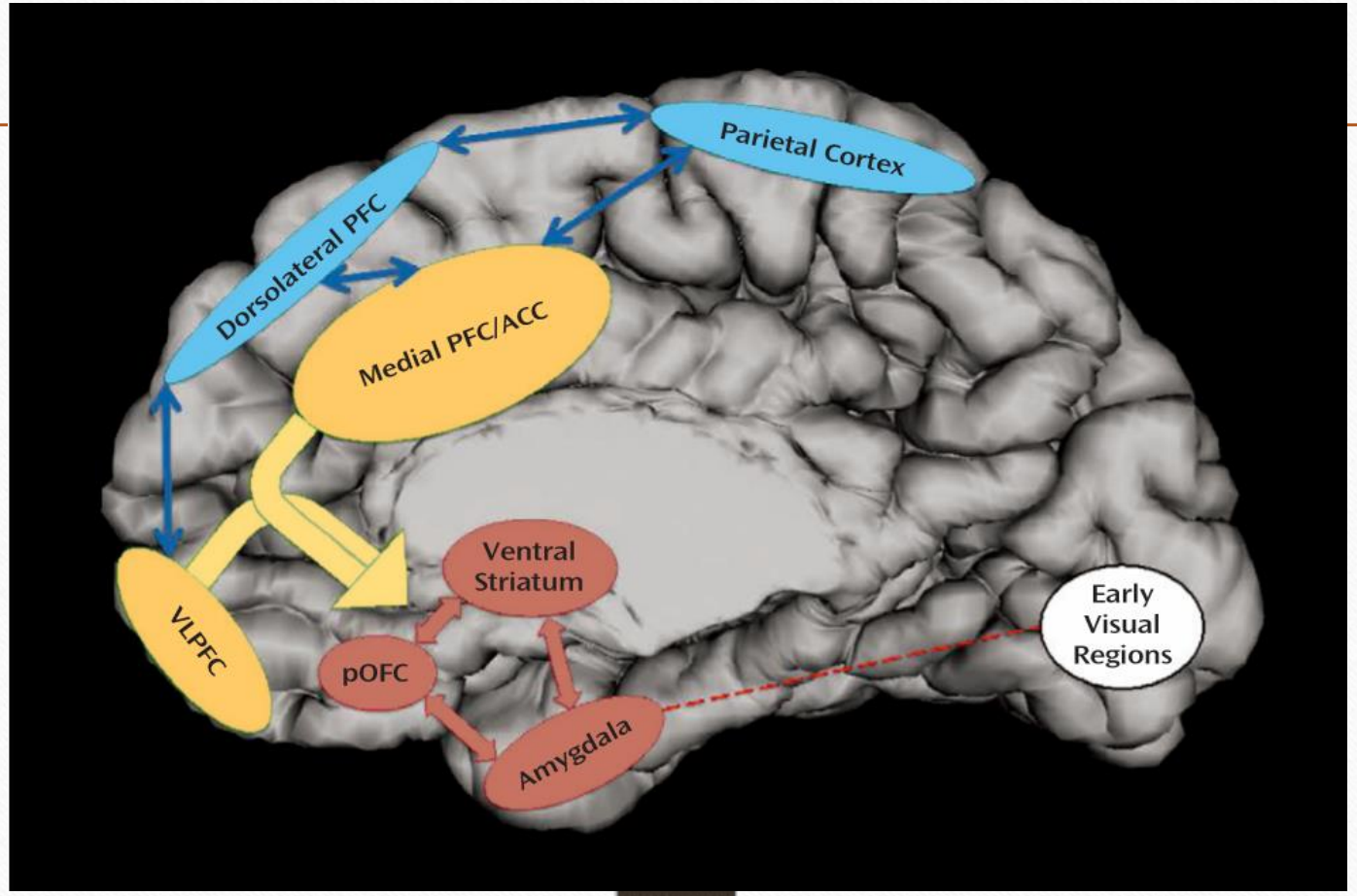
Emotion Regulation

- If an individual has dysfunction that is more focused in more lateral prefrontal/parietal cortical regions,
- then in that individual symptoms of ADHD such as inattention would predominate over emotion dysregulation.

Emotion Regulation

- Conversely, an individual with predominantly (para)limbic dysfunction may exhibit mainly symptoms stemming from emotion dysregulation *(Shaw 2014)*

The circuitry that underpins deficits in early orienting to emotional stimuli and their perception is shown in red. Regions that interface between emotional and cognitive circuits, allocating attention to emotional stimuli, are shown in yellow. Circuitry implicated in cognitive control, motor planning, and attention is shown in blue. ACC=anterior cingulate cortex; pOFC=posterior orbitofrontal cortex; PFC=prefrontal cortex; VLPFC=ventrolateral prefrontal cortex.



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