



EXECUTIVE FUNCTIONS: DEVELOPMENTAL PERSPECTIVES

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Agenda – Part I

- Definition
- Neurobiology
- Development

Part II

- Clinical Interventions
- Interdisciplinary approaches
- Early Intervention
- Dyadic Interventions
- School Based Interventions

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Executive Functions - Definitions

- Widely used term applied to various aspects of adaptive functioning.
- The meaning varies greatly depending on the knowledge and intent of the user. (McCloskey, 2009)

Varied Descriptors

- 1973 – Luria – Maintains an appropriate set in order to achieve a future goal.
- 1986 – Baddeley – Mechanisms by which performance is optimized in situations requiring the simultaneous operation of a number of different cognitive processes.
- 1986 – Stuss & Benson – Higher functions that integrate others that are more basic such as perception, attention, and memory, the ability to anticipate, establish goals, plan, monitor results, and use feedback.
- 1989 – Denckla – The ability to plan and sequence complex behaviors, simultaneously attend to multiple sources of information grasp the gist of a complex situation, resist distraction and interference, inhibit inappropriate responses, and sustain behavior for prolonged periods.
- 1991 – Welsh, Pennington – Involves strategic planning impulse control, and organized search as well as flexibility of thought and action.
- 1995 – Lezak – Capacity to engage in independent, purposive, self-serving behavior.
- 1998 – Anderson - A set of goal-directed, future-oriented cognitive skills that are essential for adaptive behavior, including the ability to organize oneself, solve problems and social behavior.
- 2000 – Nigg – Regulatory control.
- 2000 – Gioia, Isquith – A collection of processes that guide, direct, and manage cognitive, emotional, and behavioral functions, especially during active, novel, problem-solving.
- 2004 – Baron - Metacognitive capacities that allow an individual to perceive stimuli from his or her environment, respond adaptively, flexibly change direction anticipate future goals consider consequences and respond in an integrated or common-sense way, utilizing all these capacities to serve a common purposive goal.
- 2009 – McCloskey – A collection of directive capacities that are responsible for a person's ability to engage in purposeful, organized, strategic, self-regulated, goal-directed processing of perceptions, emotions, thoughts, and actions.
- 2013 – Rueda & Paz-Alonso – Multidimensional cognitive control processes that are voluntary and highly effortful, including the ability to evaluate, organize and achieve goals, flexibly adapt behavior when confronted with novel problems and situations.

Executive Control

- A broad term used to describe the neuropsychological functions of the frontal lobes, incorporates many distinctive cognitive processes.

Sample Executive Function Subdomains

Ida Sue Baron, 2004, Neuropsychological Evaluation of the Child

- Set Shifting
- Hypothesis Generation
- Problem Solving
- Concept Formation
- Abstract Reasoning
- Planning
- Organization
- Goal Setting
- Behavioral Regulation
- Common Sense
- Creativity
- Fluency
- Working Memory
- Inhibition
- Self-Monitoring
- Initiative
- Self-Control
- Mental Flexibility
- Attentional Control
- Anticipation
- Estimation


Thinking “outside the box,” Diamond, 2013

- Executive functions (EFs) make possible mentally playing with ideas; taking the time to think before acting; meeting novel, unanticipated challenges; resisting temptations; and staying focused. Core EFs are inhibition (self-control—resisting temptations and resisting acting impulsively) and interference control (selective attention and cognitive inhibition), working memory, and cognitive flexibility (including creatively thinking “outside the box,” seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances).



Popular Images - Orchestra Conductor CEO of the brain

Orchestra Conductor – Goldberg, 2001

- “S” or smart factor
 - Unintentionally can lead to describing EF as a unitary, global process.
 - CEO of the Brain – Saltus, 2003
 - Term introduced to popular culture by Saltus with the focus on increase in frontal lobe synaptic connectivity leading to developmental improvements in self-direction and self-control.
 - Contributed to the error of thinking of EF as a unitary process.
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Executive Functioning & IQ –

“ If Johnny is so smart, why can’t he figure out how to get started?”

Is Betsy is so smart, why can’t she keep her school work organized?”

If Deshawn is so smart, why does it take him so long to “get into gear?”

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An important distinction

- The distinction between general intelligence and EF has been established in numerous studies.
- Only moderate correlations were found when EF tests were compared to adult IQ tests (Crockett, Bilsker, 1986)
- The operational definitions of intelligence, including reliability and validity, that have been used to develop tests of intelligence have contributed to general misunderstanding.

How are EF functions related to intelligence?



High intelligence isn't a guarantee of flexible thinking. An extremely bright individual can display debilitating cognitive rigidity or inability to "get the rules" of a situation and meet the social expectations of others.

Lower intelligence doesn't preclude the possibility of good common sense and creativity or the ability to think "out of the box" to solve problems.

The ability to organize a behavioral response to solve a complex problem


- Learning new information, systematically searching memory, activation of remote memories, appropriate prioritization of external stimuli, attention, generation of motor programs and use of verbal skills to guide behavior.

Top Down – Bottom-Up Self-regulation - Executive functions.

- Most theories of EF have considered primarily the top-down aspects of self-regulation, that involve primarily: working memory, response inhibition, and shifting.
- Self-regulation tends to be defined as a broader concept that encompasses EF (Blair 2016), and usually refers to any type of regulation that is adaptive for the individual, including bottom-up mechanisms such activation and arousal (Tucker et al. 1995).

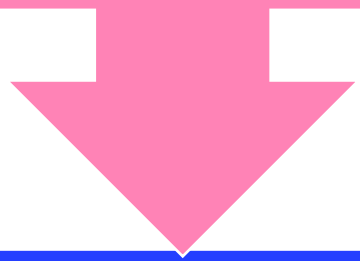


Further distinction - Hot vs Cold EF

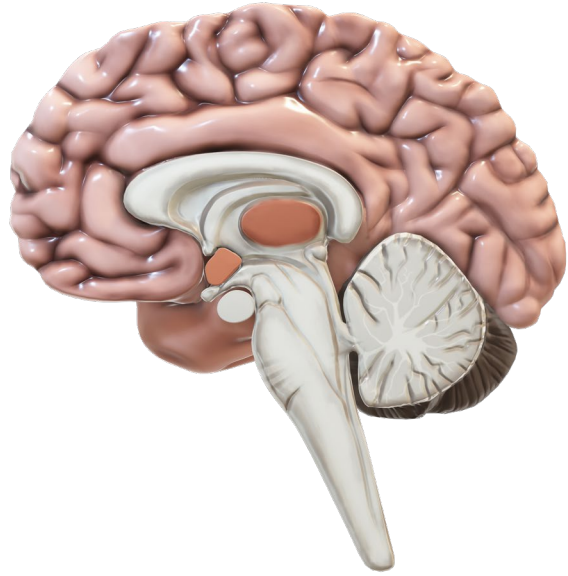
- Credited to work of Zelazo & Muller (2002).
 - A distinction between cool and hot EF is often made based on whether a problem involves abstract versus motivational aspects. (Nancy Garon, 2016, A Review of Hot Executive Functions in Preschoolers - Journal of Self-Regulation and Regulation, 2016)
 - Hot EF is elicited when people care about the problems they are attempting to solve, such as problems in the domain of self and social understanding (Zelazo, 2005).
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Linked to different neurological substrates

Both linked to prefrontal areas: hot EF with ventromedial prefrontal (VMPFC) areas, and cool EF with lateral prefrontal (DLPFC) areas.



Two largely overlapping brain regions strongly connected to the limbic areas, which are associated with emotional and social processing (Tsermentseli, 2016)



- The construct of hot EF is supported by neuroscientific research on the functions of the orbitofrontal cortex, which is involved in the flexible appraisal of the affective or motivational significance of the stimuli (Rolls, 2004).

Impairments in hot EF can occur in the absence of impairments of cool EF and visa versa.

- Both adult and pediatric research has shown that patients with damage to orbitofrontal cortex are often unimpaired on measures of classic cognitive measures of EF but none the less have considerable problems in their daily lives.

Medial & Lateral OFC circuits play distinct but complimentary roles in affect & social behavior.

- Both mediate affect, impulse control and recognition of reinforcing stimuli.
- Adult studies have identified that lesions in different prefrontal regions result in distinctly different behavioral effects.

Dorsolateral orbitofrontal cortex

- Lesion studies associated more with cognitive disorders; impaired planning and response selection in goal driven behavior, impaired temporal integration.
- Purely association cortex – bridges input and output. Does not directly receive sensory information or send motor commands.



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Medial OFC



Lesions in Medial OFC shows abnormal autonomic response to socially meaningful stimuli.



Failure to assign emotional valence to an event, which would otherwise facilitate episodic memory or learning.

- Possesses strongest reciprocal association with the amygdala, which is the major source of efferents to the brainstem and hypothalamus, emotional processing by the medial OFC impacts a spectrum of endocrine, autonomic and involuntary behavioral responses.

OFC – Brain’s central emotion regulating system — Schore, 2007

- Develops post-natally
- Either positive or negative – shaped by attachment experiences and involved in critical human functions such as social adjustment.
- EF is associated with the contexts in which children develop, including their SES and their attachment relationships.
- The brain is an inherently plastic organ, continually adapting to its environment, with “sensitive periods” when regions of the brain and their corresponding functions are especially susceptible to environmental influences.

- The orbitofrontal (OFC) is OFC receives input from all the sensory modalities: olfactory, gustatory, auditory, visual, somatosensory and visceral systems as well, primarily via the thalamus.
- One of the most polymodal regions of the cortex. The OFC is an end-stage site for projections from sensory cortex.

Typically work together as part of a more general adaptive function

- One of the primary ways people solve motivationally significant problems is to step back and reflect upon them, contextualize them, and consider them in the abstract (Zelazo & Cunningham, 2007)

Neural Networks

- Intricate neural connections subserving dynamic interactions between brain regions, or neural networks, support complex cognitive processes that are not localized to brain regions functioning in isolation.

Neural Networks

- Autonomic and emotional control networks interact with sensory cortices and premotor cortex influencing complex processes of decision-making reward, motivation, social interactions, and attention.

Frontal- subcortical Circuits

Incorporate complex input to modulate the expression of cognition and emotion through behavior and movement.

5 cortically anchored circuits that provide the basis for how those circuits influence behavior and movement (DeLong & Strick)

Frontal-subcortical Circuits

- Each circuit is balanced by direct and indirect inhibitory and excitatory influences that allows for a wide repertoire of adaptive responses to shifting internal priorities or external environmental stimuli.
- The same structure, but circuits are arranged in parallel, largely segregated from each other.
- Use the same neurotransmitters and neuropeptides, with different activation patterns.

Somatic marker hypothesis (Damasio et al. 1991; Damasio 1994)

- VMPFC functioned as a convergence zone in the brain where cognition and emotion information were integrated.
- enabled quick decision making, guiding the decision maker to important aspects of the situation and reducing the amount of information to consider.
- Emphasizes the importance of bottom-up motivational processes (e.g. calculating rewards and losses over time) in the success of top-down regulation (e.g. making an adaptive decision).

- An inability to engage in bottom-up regulatory processes as occur with damage to limbic areas such as the amygdala, also leads to top-down regulatory failure. (Bechara et al, 1999)
- Proponents of the somatic marker hypothesis, acknowledge that cool EF processes such as working memory are involved in decision making, they argue that cool EF processes are dependent on the hot EF brain network (Reimann/Bechara 2010).

Self Representation

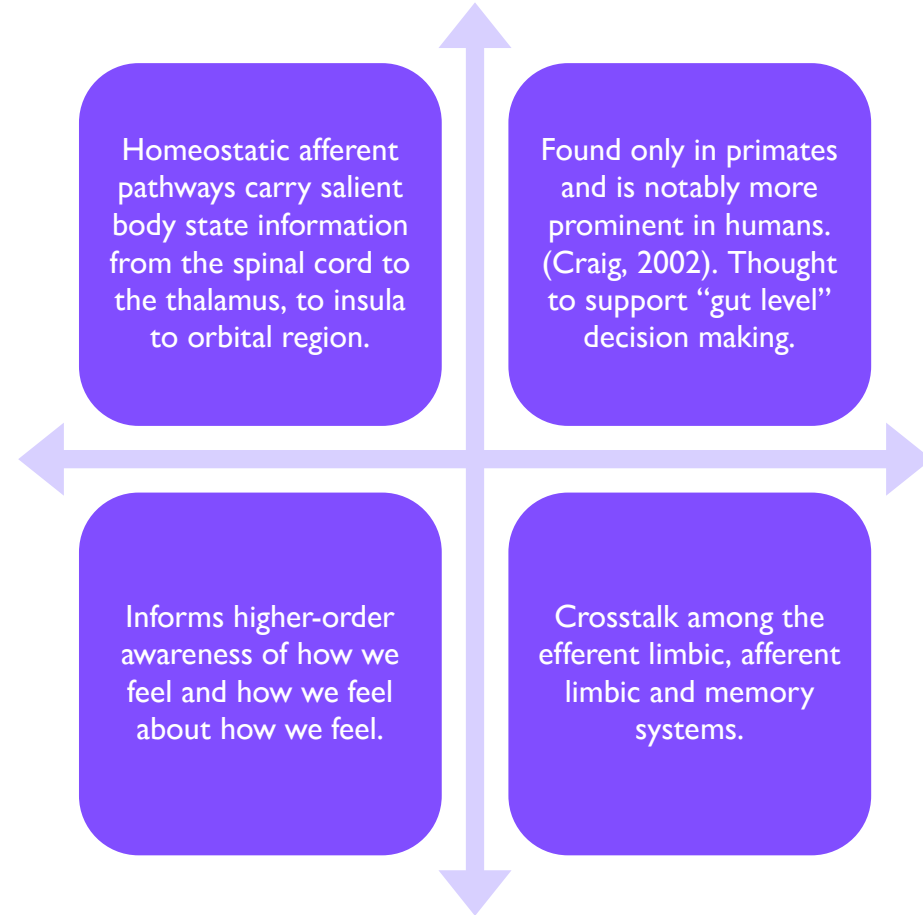
No single biological entity

A neural accomplishment
built from a dynamic set of
component processes of
interacting neural circuits.

The later maturing brain
regions support our most
sophisticated forms of self-
representation, but these
capacities are built upon
and anchored by our
earliest neural foundations.



“Gut-level” decision making network



Connecting the “here & now” with the future

- Same network that processes autonomic and body state information contains a new class of large, spindle-shaped projection neurons identified only in humans and great apes.
- Von Economo neurons.
- Auto-noetic consciousness mediates mental time travel and facilitates awareness of the self as a continuous entity across time. (Tulving, 2001)
- Numerous studies have found performance on tests of executive functioning is related to autobiographical memory retrieval.



First Year of Life

- We enter the world poised to integrate sensory into a coherent experience that sharpens the boundary between self & environment. (Rochat, 2001)
- Cross-modal perceptions links together sensorimotor information and build working models of how parallel input streams are related. I.e – when infants suck on a certain pacifier without seeing it they will later stare longer at that pacifier than one shaped differently.
- This mapping allows infants to assemble a body-centered world map that supports navigation and skill learning.
- Self-exploration accelerates the process.

Social Realm

- The cross-modal perception allows infants to detect the composition of others' actions and to make models for generating the same actions.
- Meltzoff (1983) found that some infants imitate facial expressions within the first hours of life.
- The social smile, an intentional act, emerges around 2 months and suggests an awareness that actions can influence others (Tronick, 1989)
- Joint attention, the ability to use gaze and gesture cues to share experiences with others, emerges between 9 & 12 months and is used to develop theories of mind and use affective cues.

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Early Childhood 2-4 years

Language development provides concrete feedback and self-relevant information. Toddlers better comprehend and will more often reference their own mental lives.

By age 3 they will routinely speak of their thoughts and beliefs (Dunn, 1991) and know that thinking occurs internally and cannot be seen.

By age 4, children can reliably pass theory of mind tests.

Gains in episodic memory, encoding speed, and memory retention allow children to organize their experiences into more extended narratives.

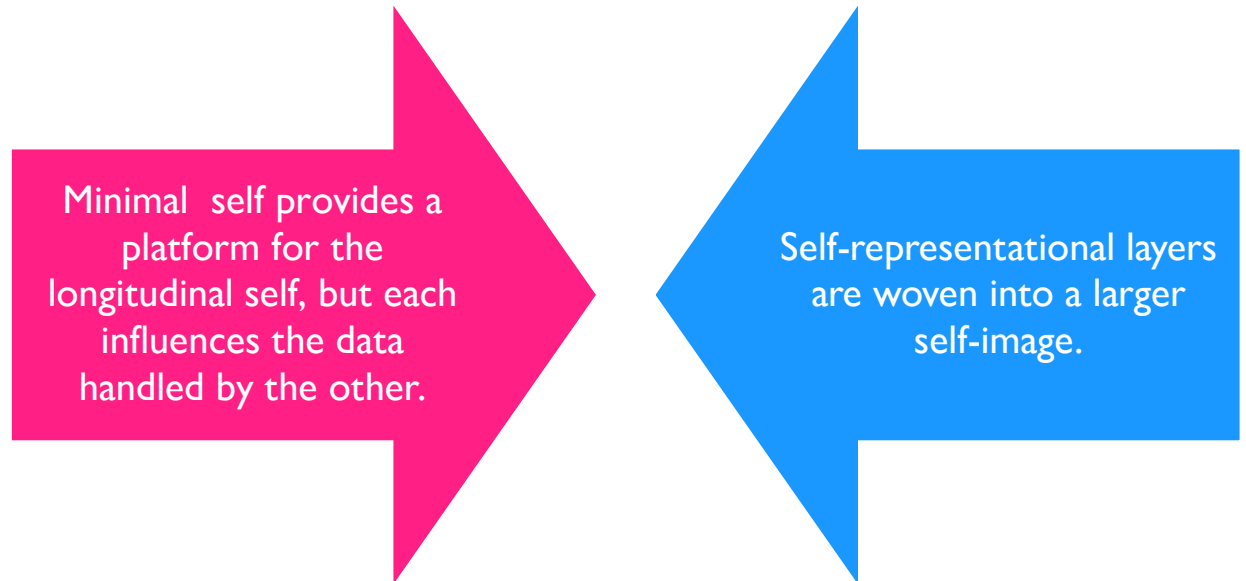
Childhood & Adolescence

Greater capacity for previously disjointed self-concepts to become linked, nuanced and elaborated.

Socialization and increased cognition allow for evaluation of self against abstract social standards, which become internalized to guide behavior and goals (Higgins, 1991)

Adolescence heightens awareness of others' opinions, and increased capacity for introspection and relating internal states to the imagined past, present, or future.

The Minimal Self & Longitudinal Self



Minimal Self



- Organizes processing streams of interoception and exteroception
- Interoception – mapping the internal body state in consciousness.
- Exteroception – Body centered world map - tracking the self within the gravitational field. Proprioceptive-kinesthetic, somatic, visual, auditory and vestibular data are integrated into a spatially refined image and used to construct an egocentric world map.

Longitudinal Self – Autonoetic Consciousness

- Takes the moment to moment experience of the minimal self and relates them to extended individual life histories.
- The glue that holds the self together. "Today I read an article on EF....I teach....I am an educator."