Brain & Cognitive Development: A Focus on Myelination and Executive Functions

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9th Annual Wyeth Nutrition Science Center Global Summit

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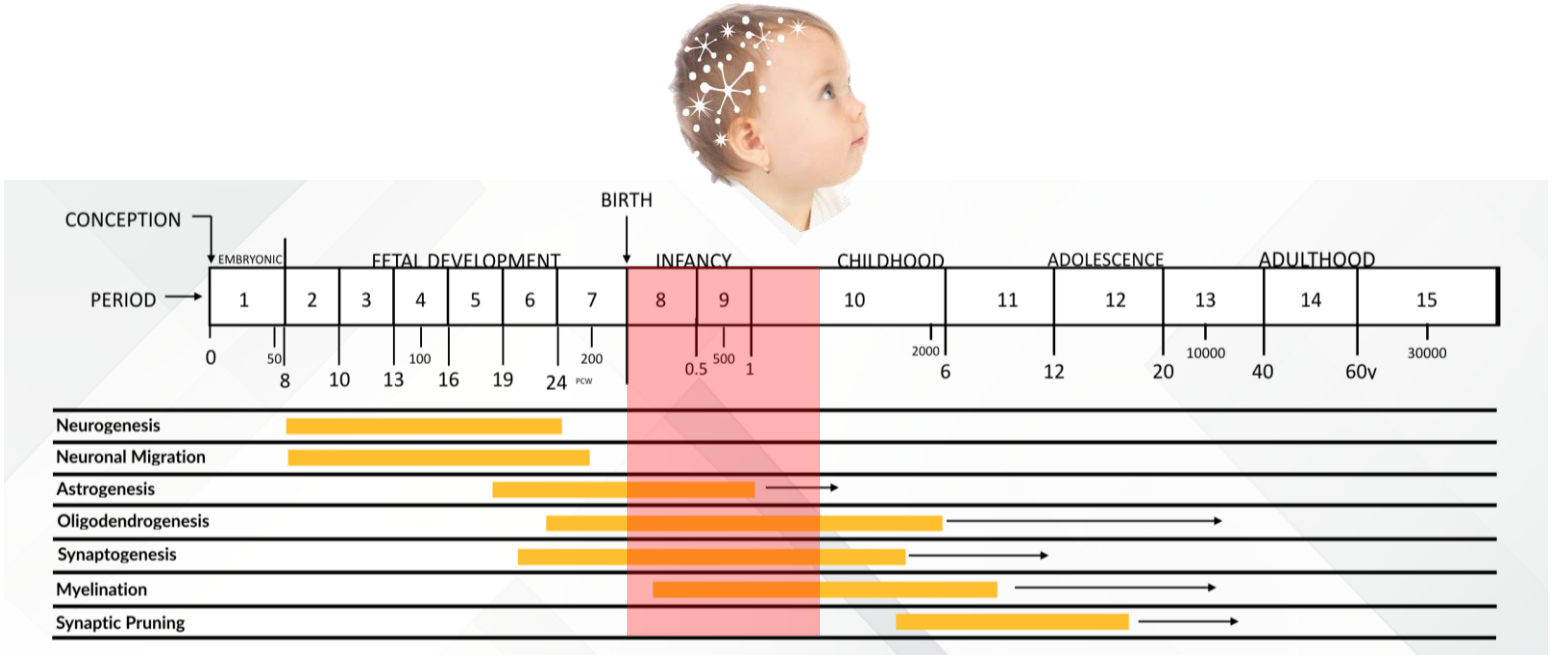
Presentation Outline

- Brain Development in Early Life
- Brain Structure & Function: Myelination and Cognition
- Executive Functions – building core cognitive capabilities for life

Brain Development – early life

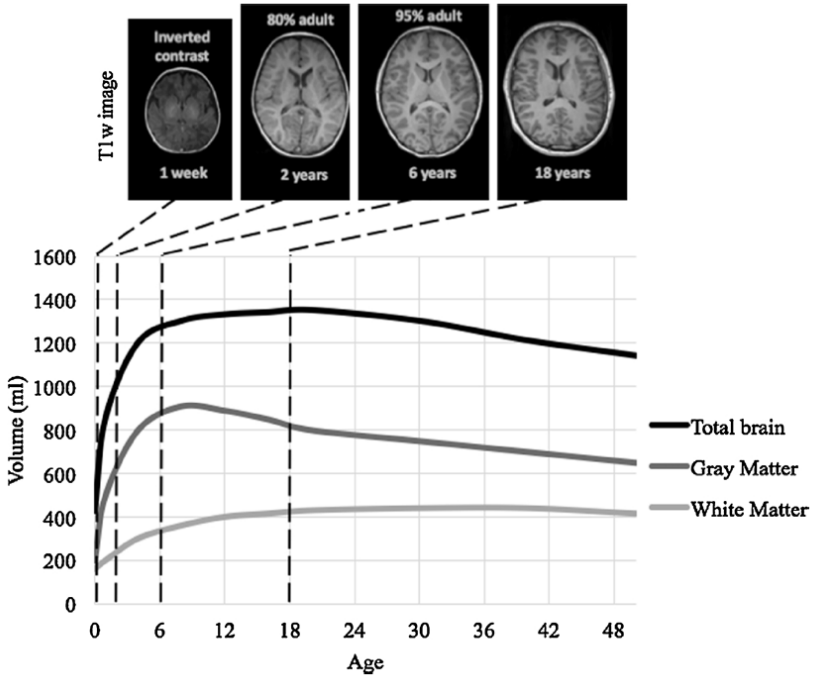


Adapted from Silbereis et al., 2016

Brain Development – early life

- Children's brains are significantly different from the adult brain as the organization and properties of brain structures change with age[1]

- The early brain develops with a level of plasticity; this facilitates both adaptive changes, representing potential **opportunity**, and malformations, reflecting potential vulnerability[2]



[1]Vân Phan et al., 2018, [2]Gao et al 2017

Influencing Factors

Gene expression (nature)

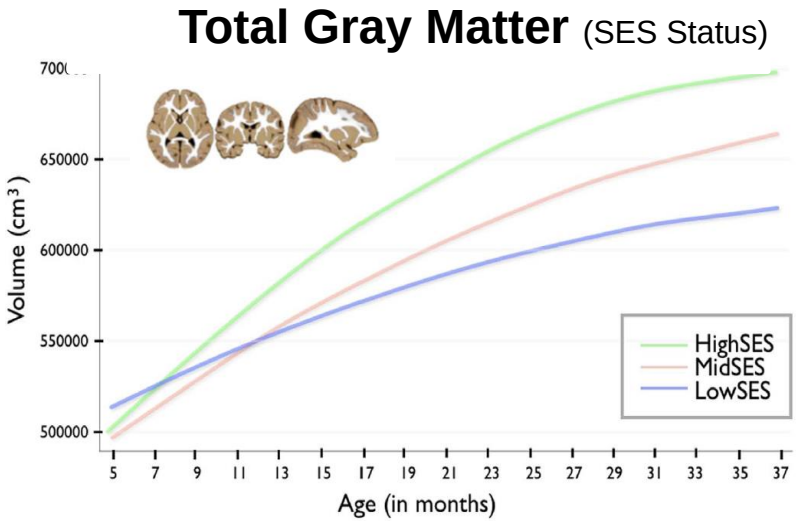
Environmental factors (nurture)

→ Molecular cues that guide development and are dependent on environment and experiences of the developing child

Influencing Factors

Environmental factors

- Socioeconomic status (SES)
- Social mobility
- Nutrition
- Social interactions
- Stress
- Ubranisation
- Pollution



Hanson J.L. et al., PlosOne, 2013

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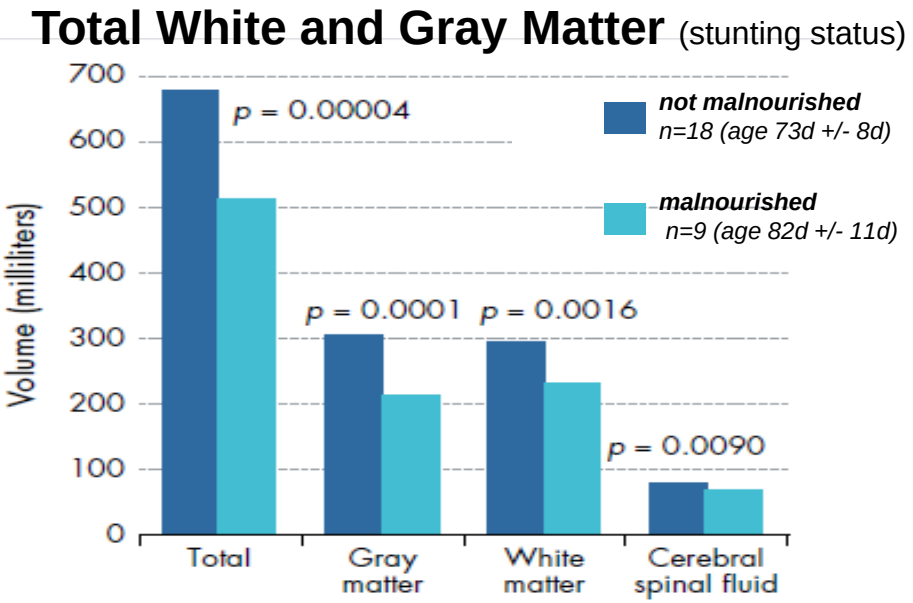
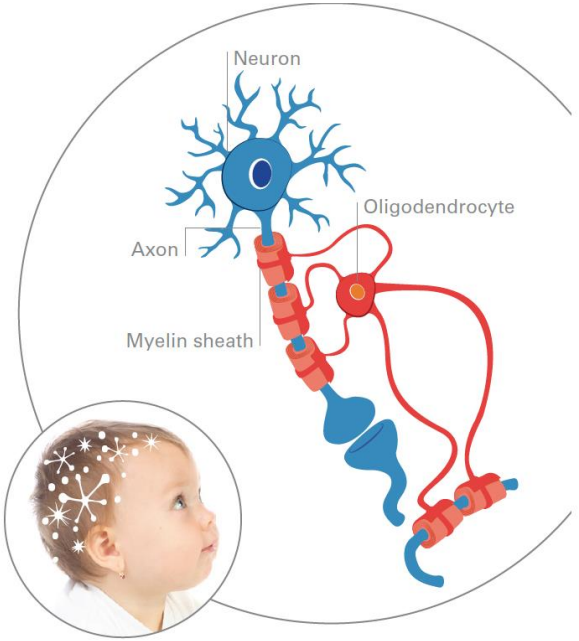


Source: worldbank.org/en/publication/WDR 2018, using data from Nelson and others (2017). Data at http://bit.do/WDR2018-Fig_S2-1.

Myelination

Myelination is a key part of neurodevelopment[1,2]

- Wrapping of nerve fibers (axons) with lipid-rich sheath
- Ensures fast, efficient & synchronized communication between cells and networks
- Protects the neuron
- Matures alongside cognitive and behavioural development

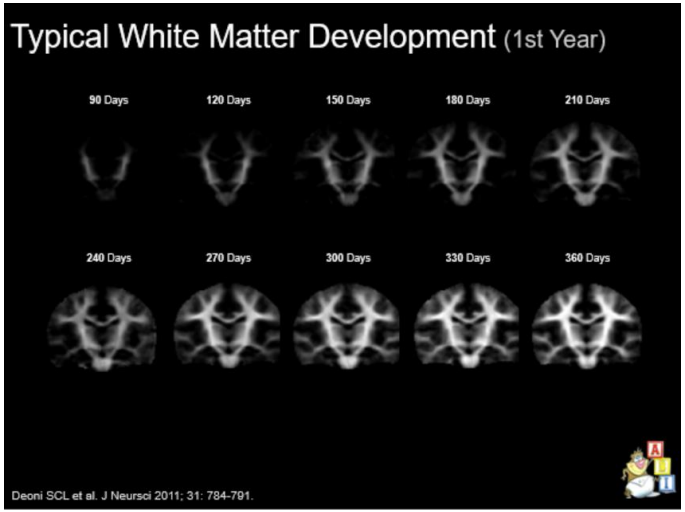


[1]Silberis 2016; [2]Deoni et al 2011

Myelination & Cognition

Clinical studies demonstrate the link between myelination and cognition, including:

- general cognitive ability[1]
- language[2] & reading[3]
- working memory[4]
- processing speed[5]
- sensory reactivity[6]



[1]Schmithorst et al., 2005; Deoni et al., 2015; [2]Büchel et al., 2004; O'Muircheartaigh et al., 2013; [3]Nagy et al., 2004; Beaulieu et al., 2005; [4]Nagy et al., 2004; Short et al., 2013; [5]Turken et al., 2008; Bartzokis et al., 2010; Lu et al., 2013; [6]Weinstein et al., 2014

Myelination & Cognition[1]

Objective

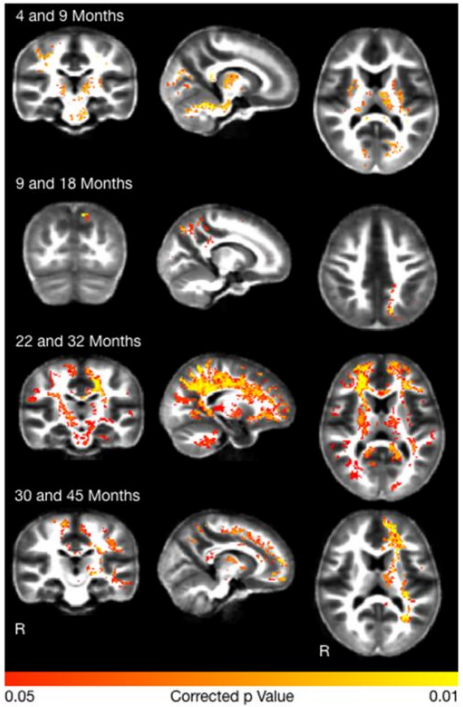
To examine the longitudinal relationship of maturing brain myelination to variability in cognitive skills.

Population

N = 187 children with repeated MRI (Myelin Water Fraction) and cognitive assessments (MSEL) between 2 mo and 6 yrs of age

Results

Marked age-related variability in repeated cognitive measures that was variably related to on-going changes in myelination.



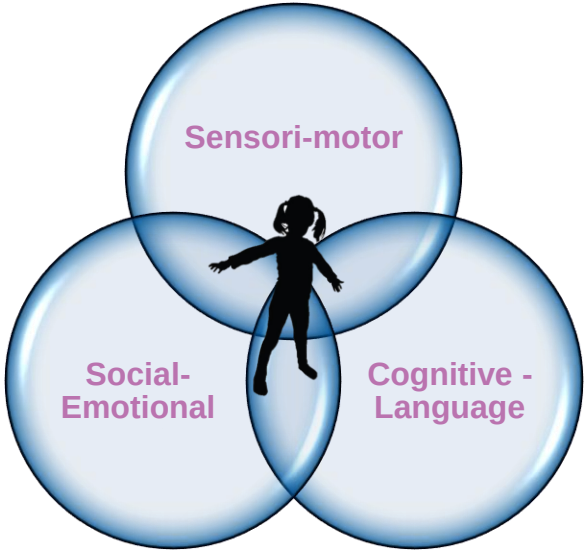
[1]Deoni et al 2019

Brain & Cognitive Development

- Changes in neurobiology parallel behavioral maturation → milestones[1]

Continuous learning process of gaining:

- Sensory
- Motor
- Cognitive
- Langage
- Social &
- Emotional abilities



[1]Silbereis et al., 2016

What are Executive Functions (EF)?

- EFs are a family of key **mental processes** that **organize**, manage **information** and control **behavior**[1]
- 3 core EF:

  Inhibition (inhibitory control, including self control (behavioural inhibition and interference control (selective attention and cognitive inhibition)

  Working memory

  Cognitive flexibility (also called set shifting and mental flexibility)

[1]*Diamond A. 2013*

What are Executive Functions (EF)?

3 core Executive Functions[1,2]

- Planning and organisation
- Flexible thinking
- Emotions & behavior controls
- Multi-tasking
- Solving complex problems
- Learning rules
- Making decisions
- Motivation
- Concentrating
- Self-awareness

[1] Diamond A. (2013); [2] Collins & Koechlin (2012)

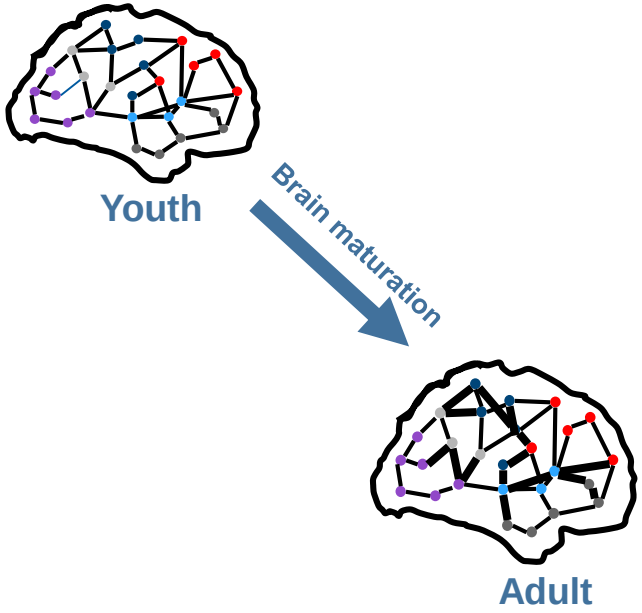
Development of EFs – related to other cognitive skills

- Children are not born with EFs skills, but with the ability to develop them[1]
- EF draw on other, earlier developing cognitive skills
- Generally cognitive development proceeds from sensory, motor and early language activity to social interaction and finally higher order cognition and executive functions[2]

[1] https://developingchild.harvard.edu/science/key-concepts/executive-function;[2]Dajani et al 2015

Development of EFs – related to brain connectivity

- EF are orchestrated by neural activity within the prefrontal cortex (PFC)[1] that is connected with other brain regions
- Those networks of different brain regions continuously process and share information with each other, either via anatomical links (structural connectivity) or via simultaneous activation of spatially separate regions (functional connectivity)[2-4] and they develop from local to wide-spread networks



[1]Best & Miller (2010), [2]Huang & Ding (2016), [3]van den Heuvel & Hulshoff (2010), [4]Sporns O. (2013).

EFs as core cognitive capabilities for life

- EF are skills for life and learning[1]
- EFs are skills essential for success in school and in life as well as cognitive, social, and psychological development[2]
  - → Mental & physical health
  - → Quality of life
  - → School readiness
  - → Job success
  - → Marital harmony
  - → Public safety
- They can be more predictive than IQ or socioeconomic status[3]

[1] www.developingchild.harvard.edu/resources/; [2]Diamond A (2013), [3]Diamond A (2016).

Factors influencing the development of EFs[1-4]

- Neural maturation
- Schooling & education
- Language
- Social environment & connections
- Positive relationships with adults
- Physical & mental activity
- Practice
- Creative play

- Factors disrupting brain architecture
- Negative stress
- Neglect & violence

[1] https://developingchild.harvard.edu/science/key-concepts/executive-function/; [2] Matsuda et al. 2017; [3] Baum et al. 2017; [4]Best & Miller (2010)

Wrap up & key messages

Key messages

- The first years of life are a rapid & dynamic period for brain maturation. Most brain processes during that period are primarily focused on connecting the brain, e.g. myelination
- The resulting connectivity is central to establishing cognitive functions, such as Executive Function (EF). EF development and maturation is fundamental to success in school, life as well as health & well-being.
- Many factors influence brain growth and myelination; early life nutrition is an important and modifiable factor that can shape myelination and, consequently, cognitive development including executive functions

Brain & Cognitive Development: The Role of Polar Lipids

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