

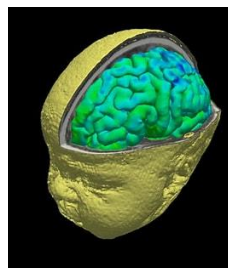
Stronger Together: The Neuroscience of Early Brain Development & Policy Implications

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October 24, 2025
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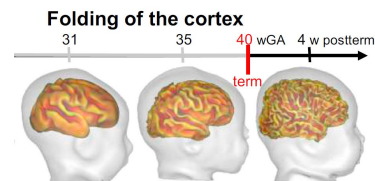
Learning Intentions: participants will be able to

1. Describe early brain maturation and timing of critical periods of healthy brain development
2. Describe the importance of neurogenesis and neuroplasticity for learning and communication
3. Describe the importance of play & experience to prevent learning and behavioral issues in later childhood and adolescence
4. Summarize the brain science of preparation and prevention

Neurogenesis and Neuroplasticity:
The Human Brain is an experience-dependent organ



The Infancy of the Human Brain - Pre-term to birth



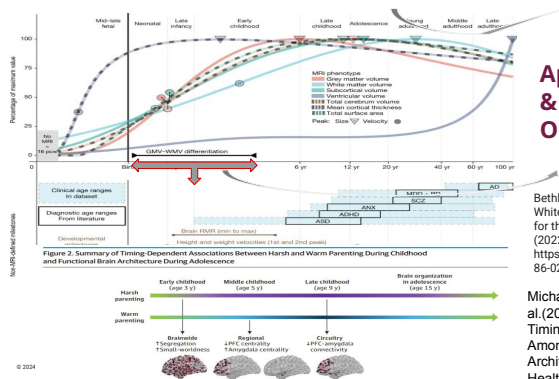
G. Dehaene-Lambertz^{1,*} and E.S. Spelke²
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<http://dx.doi.org/10.1016/j.neuron.2015.09.026>

Brain Development after birth

- Proliferation and neurogenesis
- Pruning
- Network building

Neurogenesis and Neuroplasticity

- **Neurogenesis:** Creation of New Neurons: Neurogenesis is the process by which new neurons are formed in the brain.
- **Occurs Throughout Life:** While most active during prenatal development, neurogenesis continues in specific brain regions during adulthood.
- **Plasticity and Adaptation:** Neurogenesis supports neuroplasticity, allowing the brain to adapt to new experiences and build skills based on those experiences



April 6, 2022
&
Oct. 18, 2024
1st sensitive period
birth - 5 years

Bethlehem, R.A.L., Seidlitz, J., White, S.R. et al. Brain charts for the human lifespan. *Nature* (2022).
<https://doi.org/10.1038/s41586-022-04554-y>

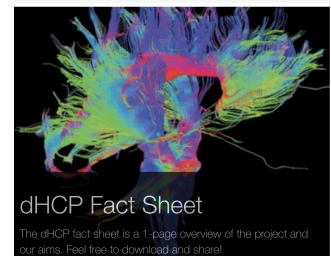
Michael, C. et al. (2024) Developmental Timing of Associations Among Parenting, Brain Architecture, and Mental Health. *JAMA Pediatrics*

Developing Human Connectome Project (dHCP)

www.developingconnectome.org

Led by King's College London, Imperial College London and Oxford University - goal is to make major scientific progress by creating the first 4-dimensional connectome of early life - from 20-44 weeks post-conception age,

Linking together open-source imaging, clinical, behavioral and genetic information that researchers world-wide can use for meaningful research to enhance early brain development of all children.



Example of new Yale research utilizing dHCP data: Some major pathways for learning and social skills are evident shortly after birth



Image - Neuroscience News
10/5/25

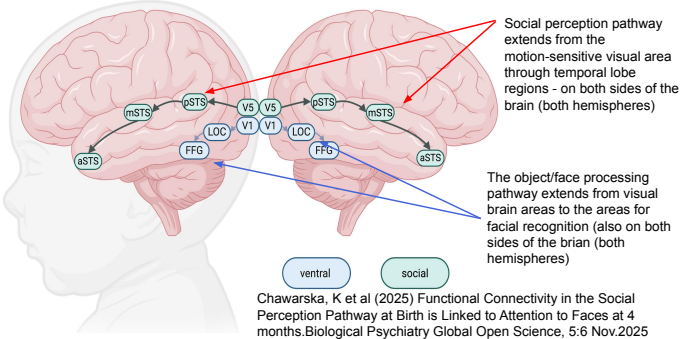
“Born to Connect:” Newborn Brain wired for Social Awareness Development

“Brain connectivity is linked to facial attention”

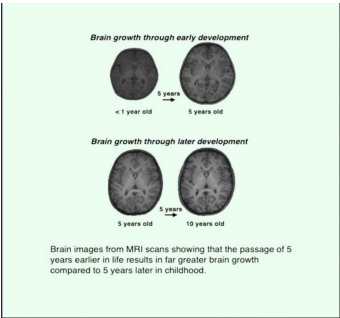
A new study out of Yale found that connectivity within the brain’s social network was already quite robust and active a few weeks after birth.

Chawarska, K et al (2025) Functional Connectivity in the Social Perception Pathway at Birth is Linked to Attention to Faces at 4 months. Biological Psychiatry Global Open Science, 5:6 Nov.2025.

Social Perception and Face Perception Pathways in the brain



New Brain Development Research of processes that underlie reading
September 19, 2025 .



The brain processes that underlie reading are found to start in utero.

“People don’t understand that learning to read is a long process with many milestones that unfold over many years.... starting with oral language.” Nadine Gaab, Neuroscience News 9/25

EI RELEVANT DETAILS OF THIS RESEARCH SHARED IN COMING SLIDES

Turetsky, T., et al. 2025 Longitudinal trajectories of brain development from infancy to school age and their relationship with literacy development. PNAS, 122:24, 1-12.

Company Name

Date

SO: Factors that affect early brain development

- Genetic factors
- Epigenetic factors
- & Environment
 - experiences
 - exposures

12

Chen, C. J., Neuhoff, C. G., Krumholz-Hanstel, L., Osherson, D. F., Marimón, N. J., Leibel, C., & Osherson, C. G. (2020). Longitudinal associations between screen time, brain development, and language outcomes in early childhood. *bioRxiv*, 2020-08-8. Chawarska, K. et al (2025) Functional Connectivity in the Social Perception Pathway at Birth is Linked to Attention to Faces at 4 months. *Biological Psychiatry Global Open Science*, 5:6 Nov.2025.

0-3 years Examples of Experiences That Drive Speech, Language & Cognitive development



Movement and exploration



Tactile, visual, auditory inputs (playing with toys/objects while naming)



Social-emotional bonding

The importance of play and peer interaction: learning as a social and communication process:



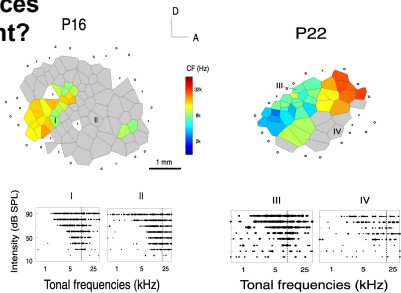
- Peer play builds turn-taking and joint attention skills in Toddlers and Preschoolers
- Peer communication builds cooperation, problem solving, taking the perspective of others, and problem solving

How do these experiences drive brain development?

1. Proliferation – A. Synaptogenesis

Proliferation – neighborhood and suburb building

- A. Synaptogenesis (neighborhoods connected by yards)



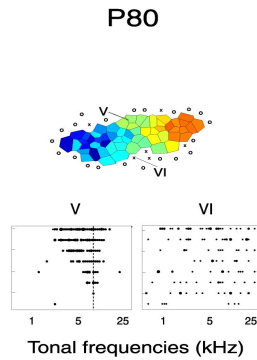
Zhang, Bao & Merzenich, Nature Neuroscience, 2001

2. Pruning

Pruning – clearing out the trees, unpaved roads, old unused houses, and other barriers to development

Competitive elimination

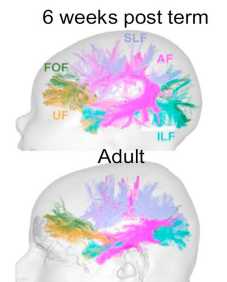
Zhang, Bao & Merzenich, Nature Neuroscience, 2001



Pruning Sculpts The Brain For Increased Efficiency but can also Limit Development, e.g language exposure

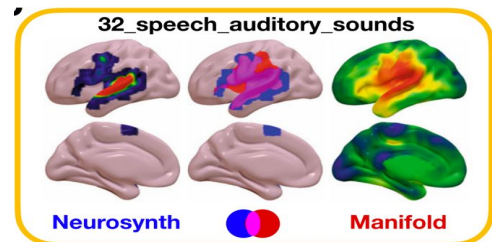
- Early in development proliferation prevails.
 - Young children make many more new connections than adults.
- Later in development pruning is more important.
 - Adults shift from a young brain that is good at learning to an older brain that is more effective and efficient but more rigid.
- We get better and better at fewer and fewer things!

DEHAENE-LAMBERTZ & SPELKE NEURON 2015



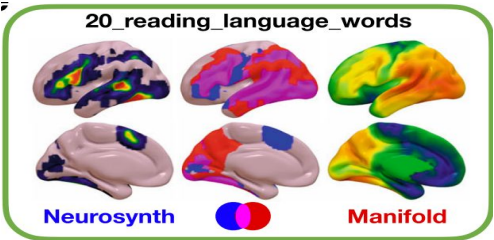
How Language, Reading & Numerical Concepts Change the Brain

Brain Regions that Develop Naturally to Learn Speech



JONES ET AL., NATURE COMMUNICATIONS | (2022) 13:1643 | <https://doi.org/10.1038/s41467-022-29047-4> | www.nature.com/naturecommunications

Brain Regions Developed Through Teaching of Reading



JONES ET AL., NATURE COMMUNICATIONS | (2022) 13:1643 | <https://doi.org/10.1038/s41467-022-29047-4> | www.nature.com/naturecommunications

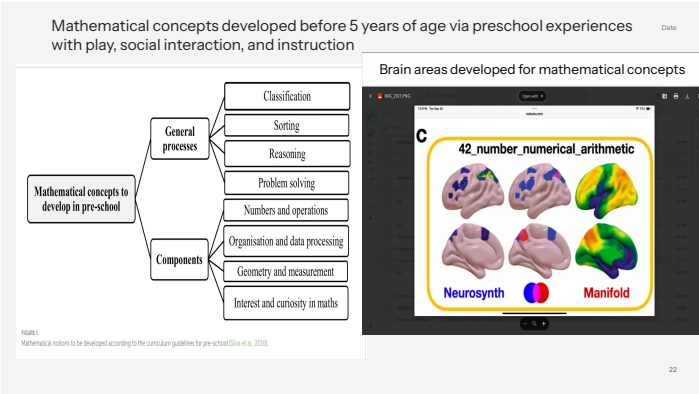


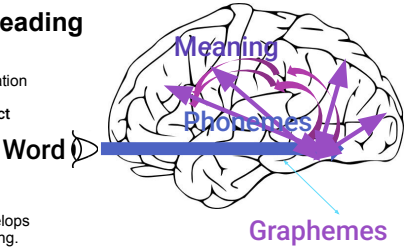
FIGURE 1
Mathematical notions to be developed according to the curriculum guidelines for pre-school (Siva et al., 2018)

It's not just about building brain regions
-connection networks are required

Brain Processes in Reading Acquisition

Reading specializes the visual association cortex of the left hemisphere for rapid recognition of letter strings and a direct connection to the speech recognition phonemic area in the left temporal lobe. Initially, children decode words deliberately. (orange arrows)

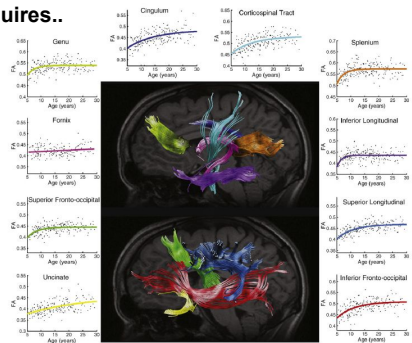
After reading automatizes with instruction and practice, the child develops rapid access of the lexicon and meaning. (purple arrows)



Network development requires..

Proliferation -
B. Axon
Development

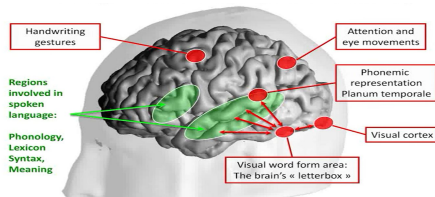
© 2024 CAMBRIDGE LEARNING, INC.



Brain Processes in Reading Acquisition

Learning to read requires creating a new *visual language link*

Connecting a visual representation of written words to brain areas for speech sounds and meaning



Dehaene, S. (2009). *Reading in the brain: The science and evolution of a human invention* (Vol. 7). New York: Viking.

Average Longitudinal Trajectories from infancy through childhood by measure.

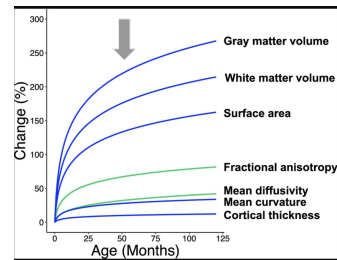


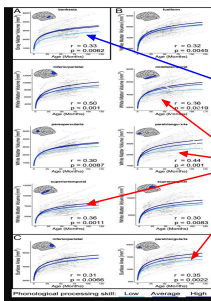
Figure 2

Notice the trajectories of the top three brain measures are most profound by 50 months (just over 4 years of age)

- Gray matter development shows development of cortical cells - specific regions
- White matter volume represents the connection pathways
- Surface area is a measure of brain size & volume

Turesky, T., et al. 2025 Longitudinal trajectories of brain development from infancy to school age and their relationship with literacy development. *PNAS*, 122:24,1-12.

Longitudinal Trajectories based on phonological processing skill (essential for decoding) in preschool versus early kindergarten



Children with low phonological processing scores tended to have less gray matter volume here. A. (Critical for speech sound perception) at birth.

And, although they maintained similar rates of development as higher scorers, they have lower rates of white matter growth in other left hemisphere brain regions important for reading, language and other academic capacities

Dark blue lines represent trajectories in associated with standardized phonological processing scores: i.e., skill level; dark blue (>115) violet represents average (85-115), and light blue represents Low (<85).

Turesky, T., et al. 2025 Longitudinal trajectories of brain development from infancy to school age and their relationship with literacy development. *PNAS*, 122:24,1-12

Figure 3

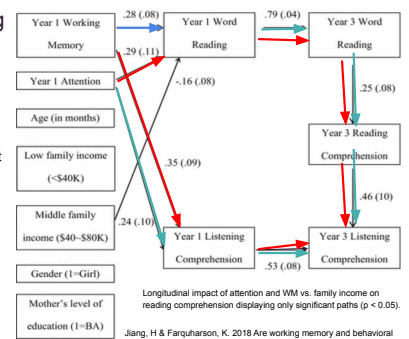
How Reading vs Listening interact by school age

Reading eases comprehension and retention when one can

- Move around within text easily
- Re-read sections if struggling to understand
- Highlight important points to revisit

When quizzed on content, older adolescent students who read material compared to those who listened to a podcast on their own time, performed significantly better.

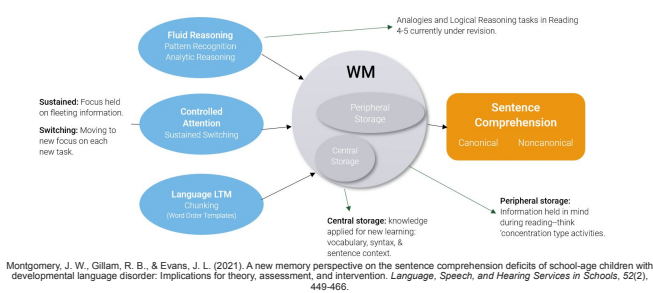
But, for students with Dyslexia, effortful decoding impairs extracting meaning and overloads working memory and for students with attention or working memory problems both word-reading and reading comprehension are impacted



Longitudinal impact of attention and WM vs. family income on reading comprehension displaying only significant paths ($p < 0.05$).

Jiang, H & Farquharson, K. 2018 Are working memory and behavioral attention equally important for both reading and listening comprehension? *Language and Reading Research Consortium*. DOI <https://doi.org/10.1007/s11145-018-980-y>

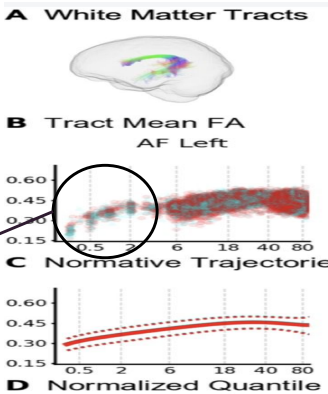
Oral Language skills affect more than reading: Cognitive Components of Sentence Comprehension



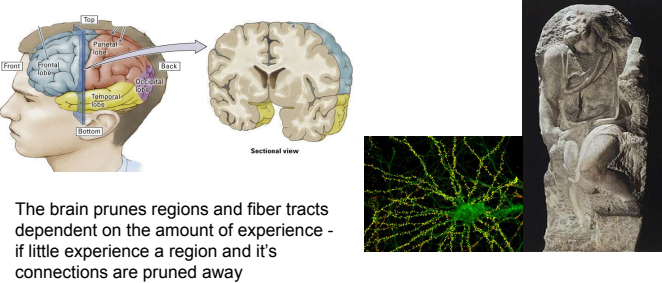
The Language Tract (AF Left)

The Left Arcuate Fasciculus (AF Left) builds to connect the regions of the brain essential for listening and understanding oral language and developing the ability to speak: words, sentences and full dialogues

Note that the first 4 years of life are when the fiber tract is laid down - around 6 years you see the proliferation



Synaptic pruning fine-tunes circuitry



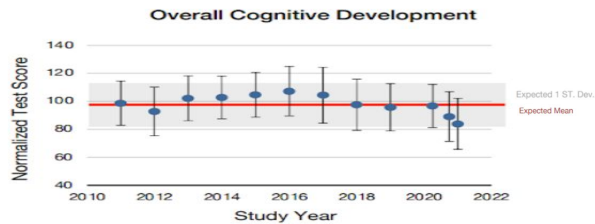
We saw evidence of the impact of limited environmental exposure on development and/or effects of pruning during experiential exposure limitations during Covid

The COVID-19 Pandemic & Early Child Cognitive Development.

Sean Deoni, PhD
Advanced Baby Imaging Lab, INSPIRE Center, Rhode Island Hospital;
Departments of Radiology and Pediatrics, Warren Alpert Medical School at Brown University

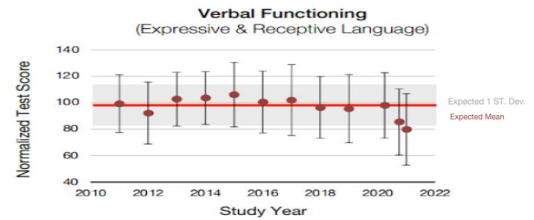


Yearly Trends in Overall Cognitive Development, Dioni et al., 2022



- Mean composite scores from a standard assessment tool (Mullen Scales of Early Learning) calculated per year.
- 783 children (401 female), 3-months to 3-years of age, 1348 total measures.

Yearly Trends in Verbal Functions, Dioni et al., 2022



- Mean composite scores from a standard assessment tool (Mullen Scales of Early Learning) calculated per year.
- 783 children (401 female), 3-months to 3-years of age, 1348 total measures.

Implications for Public Policy

Because the Human Brain is an experience dependent organ, early intervention during the critical brain period of birth to five dramatically enhances learning potential

As a result, early Intervention prevents the high educational costs of later special services

- Early intervention significantly decreases supplemental reading and math curriculum expenditures
- Early intervention can prevent many learning challenges that may result in diagnosis of learning disability and require special services
- Early intervention significantly decreases emotional and behavioral effects from Adverse Childhood Experiences that alter social-emotional networks & contribute to later disciplinary costs

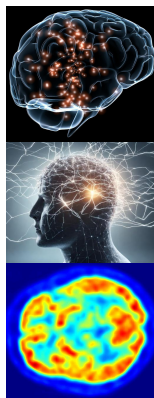
Thank you

Q & A

Appendix

Brief Brain Facts (BBF)

- It is the most advanced biological structure in the universe
- Comprised of 86 billion neurons and 100 trillion connections
- Comprised of about 2% of body weight but utilizes about 20% of the body's energy, mostly for maintaining neuron activity and cellular communication
- Neurons can transmit signals up to 268 MPH
- Synaptic connections are constantly active; at any given moment 50 trillion interactions are happening
- The brain can rewire itself through neuroplasticity, adapting to changes in environment, experiences, learning and injury.
- 7 million miles of neural connections 40x greater than the distance between earth and the moon.
- Processes 65,000 thoughts per day.



NAEP 2024: The Middle & High School Achievement Crisis

How prepared are American students when they graduate?

Reading and math skills among 12th graders fell to their lowest levels on record in the first post-pandemic assessments in 2024. The National Assessment of Educational Progress measures student outcomes on a 500-point scale for reading and a 300-point scale for math.

