Read Their Minds

An Update on Dyslexia and Brain Based Remediation

Martha S. Burns, Ph.D.

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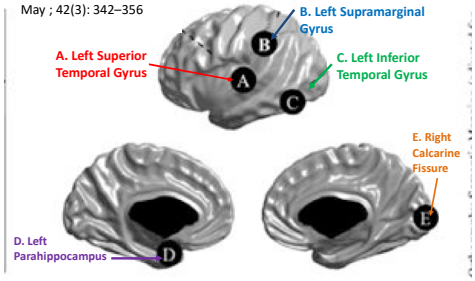
The Reading Brain

Xia et al., *Int J Behav Dev.* 2018 May ; 42(3): 342–356



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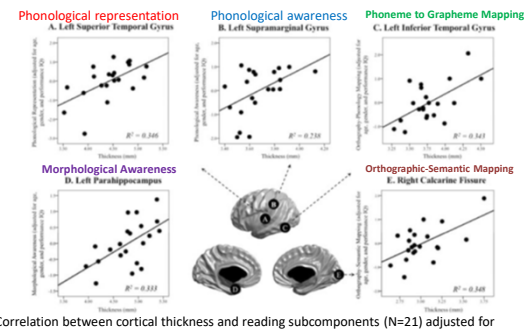

Correlation between cortical thickness and reading subcomponents (N=21) adjusted for age, gender and performance IQ

Xia et al., *Int J Behav Dev.* 2018 May ; 42(3): 342–356

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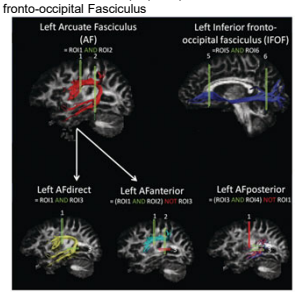
Major Fiber Tracts Associated with Reading Skill

DTI fiber tracking of the various arcuate fasciculus (AF) components and of inferior fronto-occipital Fasciculus

Cortical Brain Regions for Reading are Interconnected by Fiber Tracts



Brain, Volume 135, Issue 3, March 2012, Pages 935–948, https://doi.org/10.1093/brain/awr363

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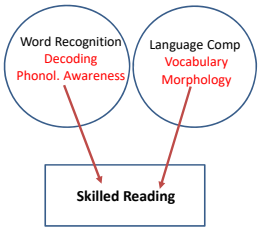
A Classical View: Simple View of Reading (SVR)

- Skilled reading involves at least two major cognitive components:
- word recognition (including decoding and phonological awareness) and
- language comprehension (e.g., knowledge of vocabulary and language structures)
- together, these strands coalesce to form what is classically known as the 'reading rope'

Scarborough HS. Connecting early language and literacy to later reading (dis)abilities: Evidence, theory, and practice. In: Neuman SB, Dickinson DK, eds. *Handbook of early literacy research*. New York: Guilford Press; 2001:97–110.



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However New Research Indicates that the SVR Components….

- Are not single entities; they are:
  - multifactorial,
  - malleable, and
  - context-dependent (Catts, 2018)
- Also, recent research indicates that skilled reading is contingent upon:
  - general oral language skills (Nation, 2019)
  - knowledge of academic language & reasoning in older students (Snow, 2018) and,
  - additional cognitive skills (Diuk et al, 2918; Spencer, Richmond and Cutting,2019)

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The Role of Executive Functions in Reading (Daucourt, et al., 2018;)

- Recent achievement research suggests that executive functions (EF)
  - a set of regulatory processes that control both thought and action necessary for goal-directed behavior,
- Are important in reading achievement
- Especially in moving from "learning to read to reading to learn"

Executive Functions (EF) Include

- The most common division of EF includes three components:
  - response inhibition, (Attention)
  - updating and monitoring of working memory,
  - mental set shifting (Flexibility)
- Some models include reasoning and problem solving

Memory and Attention Skills have also been Recognized in Oral Language Comprehension Research

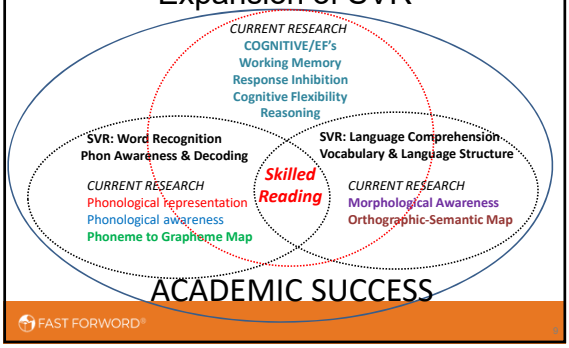
The skills below are also core factors in children with reading and language problems:

- **Memory skills**
- **Attention skills**

Syntactic Versus Memory Accounts of the Sentence Comprehension Deficits of Specific Language Impairment: Looking Back, Looking Ahead

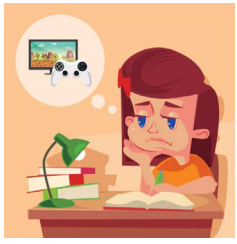
James W. Montgomery, Ronald B. Gillam and Julia L. Evans
Journal of Speech, Language, and Hearing Research, December 2016, Vol. 59, 1491-1504.

Updated View of Reading: Expansion of SVR



Reading Impairments

- For many children with reading impairments
  - the process of learning to read is rife with struggle and frustration, and
  - these children are left susceptible to adverse secondary outcomes, including anxiety and depression. Nadine Gaab, 2019



Dyslexia: Historical Perspective

- "Dyslexia"- from Greek dys-"bad, abnormal, difficult" (see dys-) + lexis "word" (taken as "reading")
- Dyslexia was a term adopted from adult neurological disorder (*alexia*) to confer a lesser, though still neurologically-based, form of reading impairment in children.
- Discrepancy Criteria Definitions – Dyslexia or Reading Impairment
  - The label given if there is a discrepancy between perceived potential to learn to read (as indicated by general ability) and actual level of reading achievement.
  - For example, a child could be diagnosed with dyslexia if he or she showed an IQ in the "normal" range but fell at or below the 10th percentile on standardized reading tests.

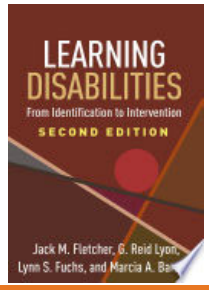
DSM 5 Definition of Dyslexia

- A clinical term falling under the umbrella:
- "Specific learning disorder that impedes the ability to learn or use specific academic skills (e.g., reading, writing, or arithmetic)"

Dyslexia: Educational Definition

- Word level reading difficulty, characterized by:
  - A core deficit in phonological processing
    - The ability to recognize and manipulate speech sounds
  - Impairing:
    - Word recognition
    - Spelling
    - Decoding

Fletcher, Lyon, Fuchs, and Barnes (2018)



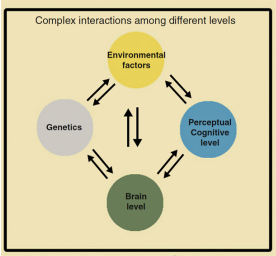
The Problems Associated with Dyslexia Often Lead to Difficulties in…

- reading fluency,
- reading comprehension,
- reduced vocabulary,
- lower content knowledge, and
- a decline in overall school performance.

Sanfilippo et al., In Press

Reintroducing Dyslexia: Early Identification and Implications for Pediatric Practice

A Multi-Deficit Approach to Dyslexia



A **Multi-Deficit approach to Dyslexia** is now considered the most accurate way to understand causation.

Interventions that do not consider all four of these dimensions of dyslexia may result in **reduced achievement levels and added intervention costs for schools**

Ozernov-Palchik, O., Wang XY., and Gaab, N., 2016

Risk Factors

(Ola Ozernov-Palchik, et al., 2016)

- **Genetic Factors**
- **Brain Level Differences**
- **Perceptual/Cognitive Level Differences**
  - Atypical sensorimotor and/or perceptual functions
  - Atypical language development and/or attention
  - Atypical PA, WM, RAN, Letter Knowledge, Vocabulary, Executive functions
- **Environmental Factors**
  - Low SES, low home literacy, stress and other adverse experiences
  - Ineffective schooling or interventions

Genetic Factors (Gaab, 2017)

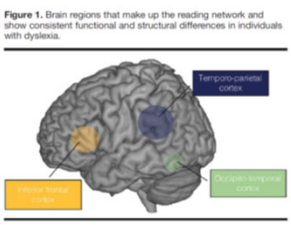
- Developmental Dyslexia is strongly heritable:
  - 50% of children with a sister, brother, mother or father with dyslexia will receive the diagnosis themselves
  - 68% in identical twins
- Specific genes known to be associated with developmental dyslexia are important drivers of brain development (ROBO1, DYX1C1, KIAA0319, DCDC2)

Brain Level Differences

August 2016, Pages 45–58
Neuroscience of education

- Lessons to be learned: how a comprehensive neurobiological framework of atypical reading development can inform educational practice. Ola Ozernov-Palchik, Xi YuYingying Wang and Nadine Gaab

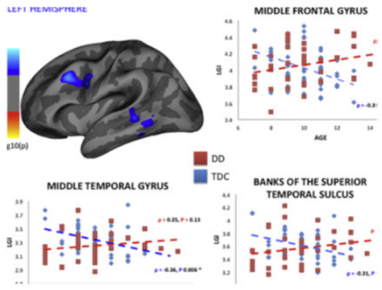
Brain Region Research



Cognitive neuroscience of dyslexia

D'Mello, A. M., & Gabrieli, J. D. (2018).. *Language, Speech, and Hearing Services in Schools*, *49*(4), 798-809.

Research on Cortical Folding



Abnormal age-related cortical folding and neurite morphology in children with developmental dyslexia

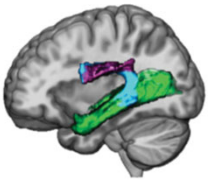
Caverzasi,et.al., 2019
NeuroImage: Clinical, Volume 18, 2018, pp. 814-821

Tractography Research

Cognitive neuroscience of dyslexia

D'Mello, A. M., & Gabrieli, J. D. (2018).. *Language, Speech, and Hearing Services in Schools*, *49*(4), 798-809.

Figure 2. White matter tracts showing structural differences in dyslexia.



Longitudinal fasciculus
Arcuate fasciculus
Superior longitudinal fasciculus

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White Matter Tract Differences – Most Notably To Date the Left Arcuate Fasciculus (AF)

(Langer, et al., 2017)

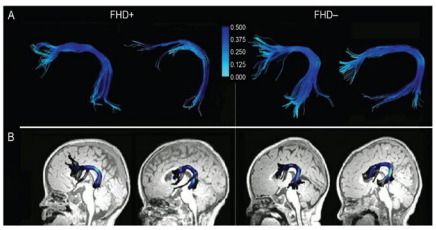

Figure 2. Exemplary left arcuate fasciculi. AF tractography in infants with (FHD+) and without (FHD−) a familial risk for DD using (A) manual and (B) automated me The intensity of the color represents the magnitude of the FA.

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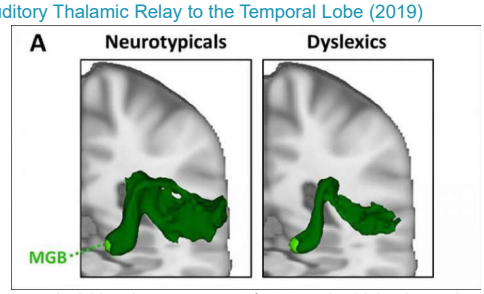
Auditory Thalamic Relay to the Temporal Lobe (2019)



Averaged probabilistic white matter connectivity for neurotypicals and dyslexics between the left motion-sensitive planum temporale (mPT) and the left medial geniculate body (MGB) (green). NeuroscienceNews.com image is credited to Tschentscher et al., JNeurosci (2019).

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Perceptual and Cognitive Level Differences

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Phonological & Orthographic Deficit Theories

Vandermosten, 2016

- Phonological deficit theory:
  - Especially in phonological awareness (i.e., the ability to process and manipulate the sound structure of words)
  - Although the Temporal Parietal region is implicated in children with phonological deficits, the research has not consistently shown causation
- Orthographic deficit theory:
  - The ability to identify written letter patterns and words as whole units (rather than letter by letter).
  - The left ventral OT area, including the fusiform gyrus, plays a key role in orthographic processing in skilled readers.

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Dyslexia-Related Differences in Pre-Readers

(Vandermosten, 2016)

- "Provide the first evidence that neurobiological differences observed in adults and children with dyslexia are not purely reading experience-driven"
- Consistent findings of TP brain region differences in at-risk pre-readers
- Supports the Phonological Deficit Theory
- Differences in Occipital temporal regions seen less consistently

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Other Pre-Reading Research on Auditory Processing and Dyslexia

- Auditory Processing Deficits were found prior to school entry
- Results support the existence of a general auditory processing impairment in developmental dyslexia that might be the cause of the phonological problems at least in a large subset of persons with dyslexia.
- Christmann, C A.; Lachmann, T. & Steinbrink, C (2015) Evidence for a General Auditory Processing Deficit in Developmental Dyslexia From a Discrimination Paradigm Using Speech Versus Nonspeech Sounds Matched in Complexity. *Journal of Speech, Language and Hearing Research.* Feb. 2015, VOL 58, 107-121

Spelling and Orthography

- English is a non-transparent language
  - There are many alternate spellings for the same sounds
    - George Bernard Shaw said we could spell "fish" as phoeti
      - 'f' sound as ph as in "phone"
      - 'I' sound as oe as in "Phoebe"
      - 'sh' sound as ti in "Nation"

Cognitive Level Differences

Executive Functions (Kidd, Donnelley & Christiansen, 2018)

- Response Inhibition
- Working Memory
  - Phonological Working Memory
  - Verbal/contextual Working Memory
  - Visual Working Memory
- Cognitive Flexibility

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Importance of Early Identification (Sanfilippo, et al 2019)

- Children are typically diagnosed at the end of 2nd or beginning of 3rd grade (and many much later),
  - after they have already failed to learn to read over a long period of time and have fallen behind their peers academically
- "This wait-to-fail approach fails to capitalize on the most effective window for intervention, which is during an earlier period of heightened brain plasticity in kindergarten and first grade"
- Screening tools are being developed to identify children at risk for reading problems as early as Pre-School
- Check-lists for pediatricians are also being developed

See also,
Ozernov-Palchec, Gaab and Zuk (2019) At MIT and Harvard
Using tablet technology in preschool and early kindergarten for the identification of children at risk for reading difficulties

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Useful Resource NCLD

- The National Center for Learning Disabilities (NCLD)
  - works to ensure that the nation's 15 million children, adolescents and adults with learning disabilities
  - have every opportunity to succeed in school, work and life.
- Provides a learning disability checklist that can identify signs of risk among children of different age groups, including children as young as in preschool

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Individual Differences (Foulkes and Blakemore, 2018; Kidd, Donnelley, & Christiansen, 2018: Wang et al. 2019)

- The Human Brain is a complex organ that varies by
  - **Genetics and epigenetic influences**
  - ***Experiences***
    - If reading is difficult for a child – that child will read less & have other experiences that build other capacities (ie., athletics, music, art)
    - These experiences may be positive but they may not translate to academic success
    - This Increases the possibility of behavioral issues associated with academic struggle



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Each Child is Unique, Exhibiting

- Perceptual strengths and weaknesses
  - Auditory, visual, sensory motor
  - Verbal, phonological, non-verbal
- Cognitive strengths and weaknesses
  - Attention, memory, reasoning
- Linguistic strengths and weaknesses
  - Word level, sentence level, content knowledge level

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A Successful Reading Approach Will Address, Accommodate and Adapt to Individual Brain/Behavior Differences

- Phonological/Decoding
  - Phonological Awareness
  - Phonological Representations
  - Decoding – phoneme to grapheme mapping
- Language Comprehension, Vocabulary and Morphology
- Cognitive Skills
  - Attention (response inhibition)
  - Working Memory
  - Flexibility of Thinking

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Even more important in adolescent readers

- While it is important to develop specific reading skills, especially at earlier ages,
- It may be equally or even more important to
  - train,
  - enhance, or
  - scaffold
- the necessary executive processes for later adolescent readers who do not excel in reading.

Wang, K., Leopold, D. R., Banich, M. T., Reineberg, A. E., Willcutt, E. G., Cutting, L. E., ... & Lu, Z. L. (2019). Characterizing and decomposing the neural correlates of individual differences in reading ability among adolescents with task-based fMRI. *Developmental cognitive neuroscience*, *37*, 100647.

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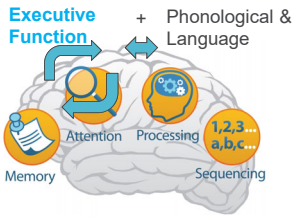
The Role of Neuroscience Technology- Simultaneously Develop Perceptual, Language, Reading and Cognitive Skills

- Carefully designed neuroscience-based technology
- **Builds the underlying capacities that are impacted in children of poverty and children with learning disabilities**



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Phonological Awareness

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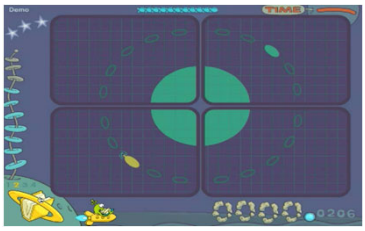
Oral Language Comprehension



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Phonological Working Memory

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Language (structure) Comprehension + Working Memory

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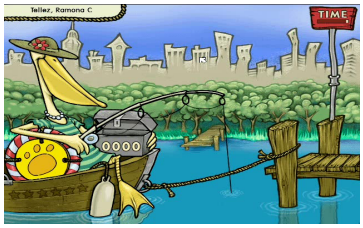
Executive Functions + Sight Word Recognition
Visual Tracking, Response Inhibition, Visual Working Memory



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Executive Functions + Language Comprehension:
Comprehension + Flexibility of Thinking

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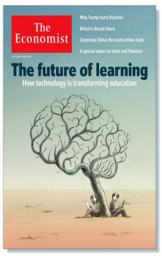
Education Technology: Together, Technology and Teachers Can Revamp Schools.

The Economist, 7.12.17



- *How the science of learning can get the best out of edtech*
- "Schools around the world are using new software to "personalize" learning.
- This could help hundreds of millions of children
- To succeed, edtech must be at the service of teaching, not the other way around.

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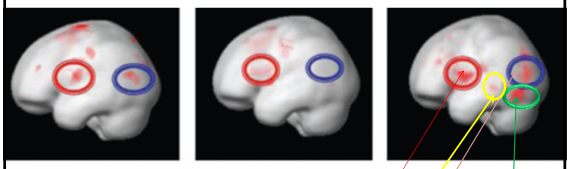
LANGUAGE AND READING AREAS ARE ACTIVATED AFTER 8 WEEKS OF FAST FORWORD TRAINING



Typically reading children Children

Reading Impaired Children Before Training

Reading Impaired After Training

Gabrieli, 2009

Left anterior inferior frontal gyrus IFG

Angular Gyrus AG

Visual Word Form Area

Left Medial Temporal Gyrus

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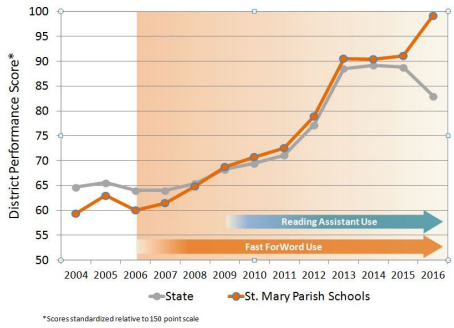
Accelerating Growth – District Wide



*Scores standardized relative to 150 point scale

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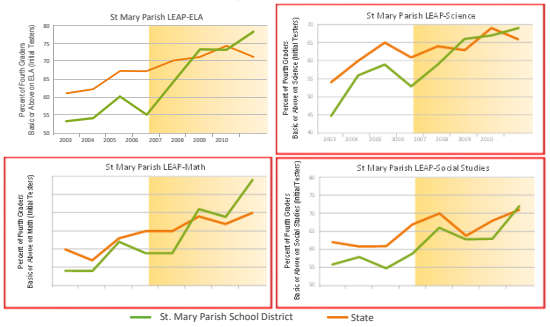
…in Multiple Subjects



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