

Cognitive Neuroscience of Reading: Development and Difficulties

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Learning objectives

- Definitions and characterizations of types of reading difficulties
- Brain-behavior in typical reading development
- Brain-behavior in atypical reading development

DSM-V: Neurodevelopmental Disorders

- Intellectual Developmental Disorders
- Communication Disorders
- Autism Spectrum Disorder
- Attention Deficit/Hyperactivity Disorder
- **Learning Disorders**
- Motor Disorders

DSM-V

- Specific Learning Disorder
 - A. Difficulties learning and using academic skills based on the presence of at least 1 of the following for at least 6 months despite provision of interventions to target those difficulties:
 1. Inaccurate or slow and effortful word reading
 2. Difficulty understanding the meaning of what is read
 3. Difficulties with spelling
 4. Difficulties with written expression
 5. Difficulties mastering number sense, number facts, or calculation
 6. Difficulties with mathematical reasoning

DSM-V

B. Affected academic skills are substantially and quantifiably below those expected given age and cause significant interference with academic or occupational performance, or daily living, as indicated by standardized test scores and clinical evaluation.

C. Learning challenges began during school-age years but may not manifest until demands for affected academic skills exceed individual's capacities.

DSM-V

D. Learning difficulties are not better accounted for by intellectual disabilities, uncorrected visual or auditory acuity, or other mental or neurological disorders, psychosocial adversity, lack of proficiency in language of academic instruction, or inadequate educational instruction.

DSM-V

- Evidence required:
 - Student’s history
 - School reports
 - Psychoeducational assessment

 - **NOT ADMISSIBLE: brain data**

Diagnostic codes



- 315.00 SLD with impairment in reading (i.e., Dyslexia)
 - Word reading accuracy
 - Reading rate or fluency
 - Reading comprehension
- 315.2 SLD with impairment in written expression
 - Spelling accuracy
 - Grammar and punctuation accuracy
 - Clarity or organization of written expression
- 315.1 SLD with impairment in mathematics (i.e., dyscalculia)

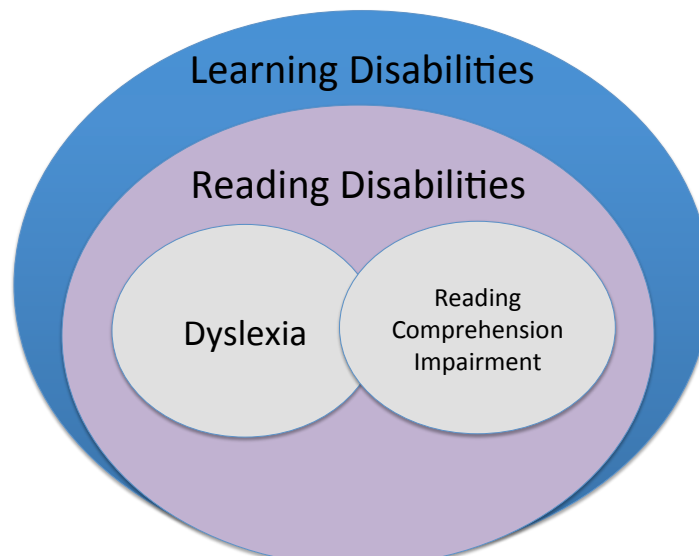
Alternative term: Dyslexia

Alternative term: Dyscalculia

DSM-V: Severity

- Required to specify current severity
 - Mild: some difficulties learning skills in 1 or 2 academic domains but may be able to compensate or function well with accommodations
 - Moderate: marked difficulties learning skills in 1 or more academic domains and unlikely to become proficient without intervals of intensive and specialized teaching during school years
 - Severe: severe difficulties learning skills, affecting several academic domains; the individual is unlikely to learn those skills without ongoing intensive individualized and specialized teaching

Contextualizing Reading Difficulties



Simple View of Reading

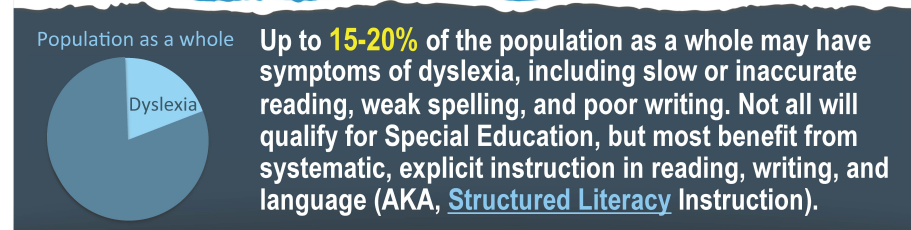
- Decoding x Listening Comprehension = Reading Comprehension
- Link between reading comprehension and decoding decrease over time
- Link between reading comprehension and listening comprehension increase over time

Defining Dyslexia

- Neurobiological in origin
- Difficulties in accurate and/or fluent word recognition and by poor spelling and decoding abilities
- Deficit in the phonological component of language
- Unexpected in relation to other cognitive abilities and the provision of effective classroom instruction
- Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge
- Exclusion of cultural, educational, environmental, or other disabilities
- **NOT ADMISSIBLE: brain data**

(Lyon et al., 2003)

How widespread is dyslexia?



Find solutions at the International Dyslexia Association (IDA) • ida.org
Source: IDA Fact Sheet, "[Dyslexia Basics](#)" • Moats & Dakin (© 2016 Cowen For IDA)

Labels

- Value
 - Educational services
 - Insurance and legal issues
 - Social community
 - Cultural relevance



Many Paths to Reading Difficulty

- Decoding
- Fluency
- Strategies for comprehension
- Background knowledge
- Multi-Language Learners
- Task demands



Goal + Learner + Context

Headlines

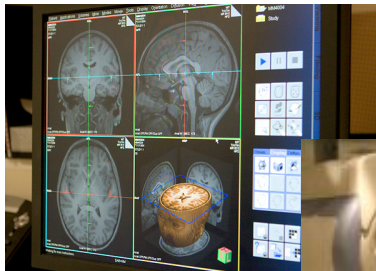
- **Definitions and characterizations of types of reading difficulties**
 - Labels and criteria vary widely for reading difficulties
 - Equifinality emphasizes the multiple ways students can have the same label but vary in their characteristics
 - We lack a single theoretical explanation of reading disabilities, but have multiple approaches to understanding deficits

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Functional Magnetic Resonance Imaging

- High quality images
- Radio waves & magnetic field
- No radiation

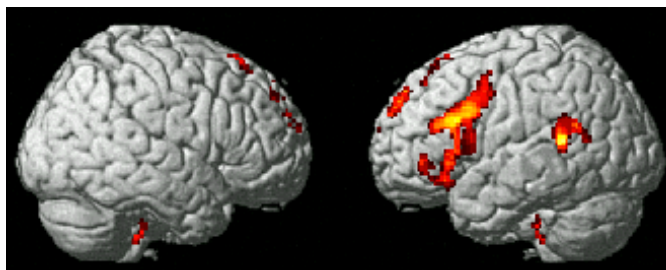


How does fMRI work?

1. Ask a question suitable for fMRI use
 - What are the neural correlates of reading?
2. Isolate the area of interest
 - Must be operationally defined
3. Design an fMRI paradigm
 - Intermix experimental and control trials of the paradigm
4. Identify activations unique to the experimental trials

fMRI Images

- Statistical map
- Group average
- Comparison: Experimental vs. Control



Understanding fMRI Images

What do they tell us

- Areas recruited for a particular task
- Group averages
- Group differences
- Activations for aspects of reading
- Areas most involved

What do they not tell us

- A dynamic story
- Timing of activations
- Individual differences
- Activation for reading as a holistic experience
- Every area active

Resources on Education Neuroscience

- Berninger, V.W., Richard, T.L. (2002). Brain Literacy for Educators and Psychologists. Academic Press.
- Mind, Brain, and Education Journal
- <http://www.learner.org/courses/neuroscience/index.html>
- [Best Evidence Encyclopedia: www.bestevidence.org](http://www.bestevidence.org)
- <https://www.gse.harvard.edu/uk>

The Reading Brain

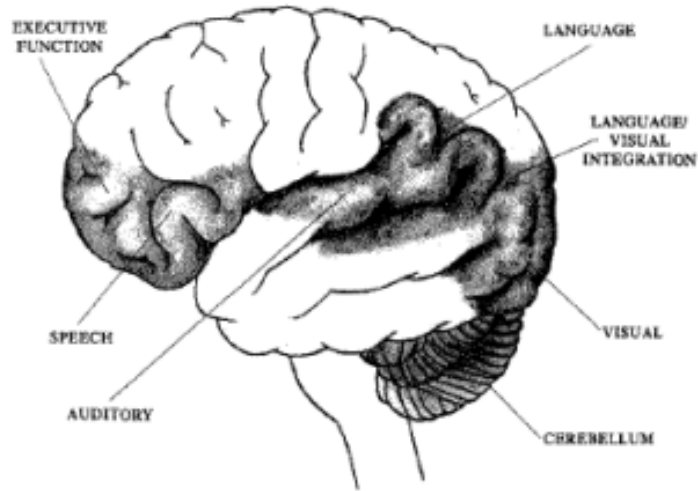
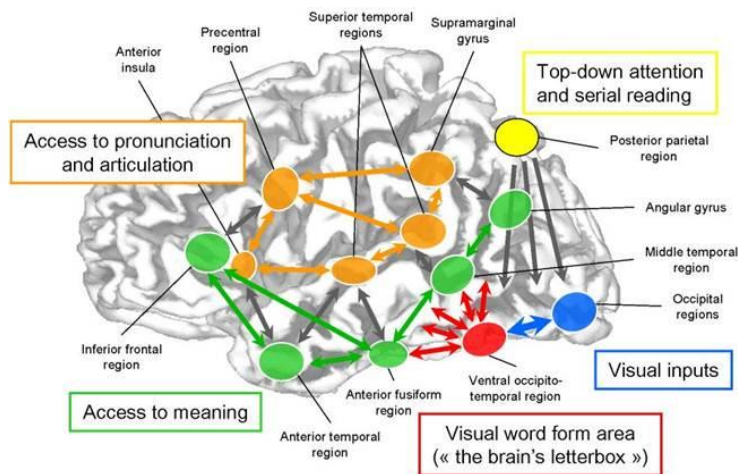


Figure 7-5: Cumulative Dyslexia Hypothesis

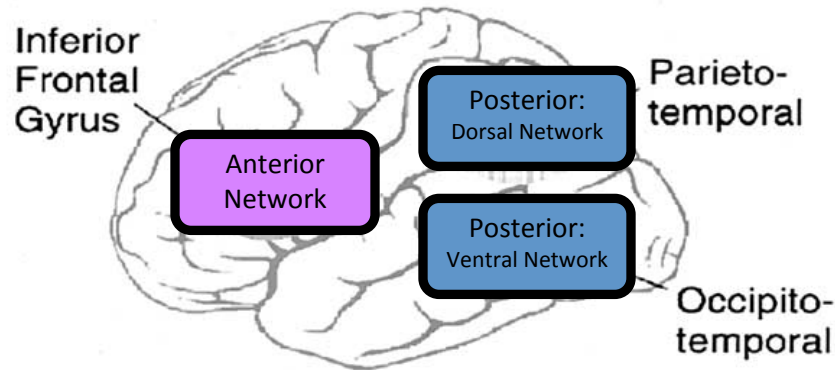
(Wolf, 2007)

Cortical Networks for Reading

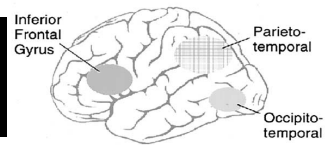


(Dehaene, 2009)

Core Reading Brain Networks

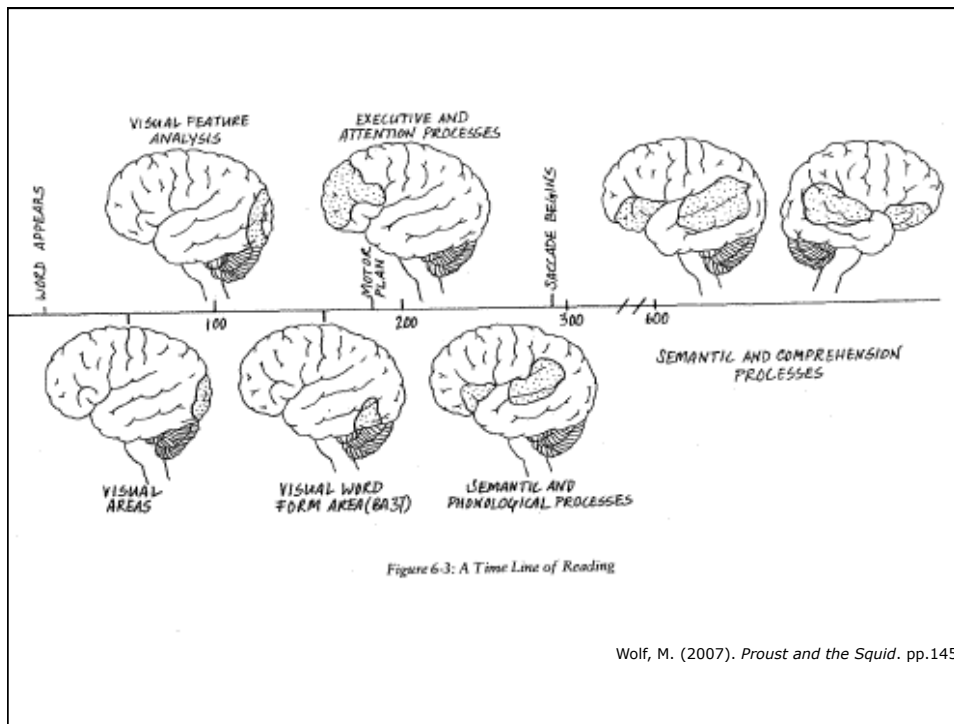


Reading Brain Networks



- **Anterior**
 - Motor production
 - Processing of low-frequency exception words and nonwords
- **Posterior – Dorsal**
 - Efficient word reading & phonological processing
- **Posterior – Ventral**
 - *Automatic* recognition of printed words

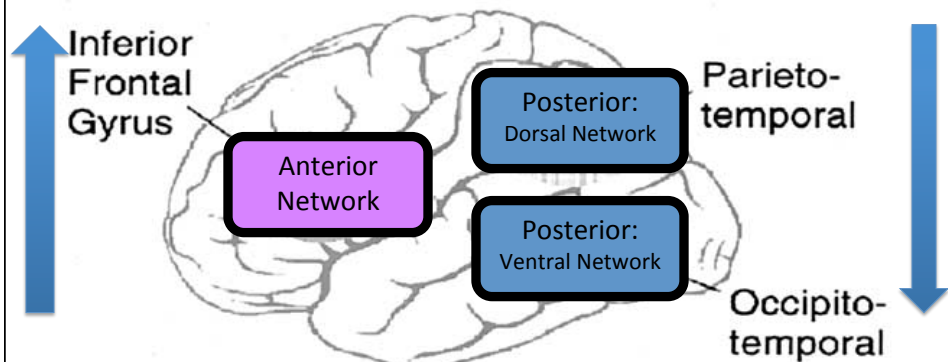
(Cohen et al., 2000; Fiez et al., 1998; Shaywitz et al., 2002)



Characteristics of Developmental Dyslexia

- **Anterior *hyper*activation**
- **Posterior *hypo*activations**
- Recruitment of **right hemisphere** homologous regions

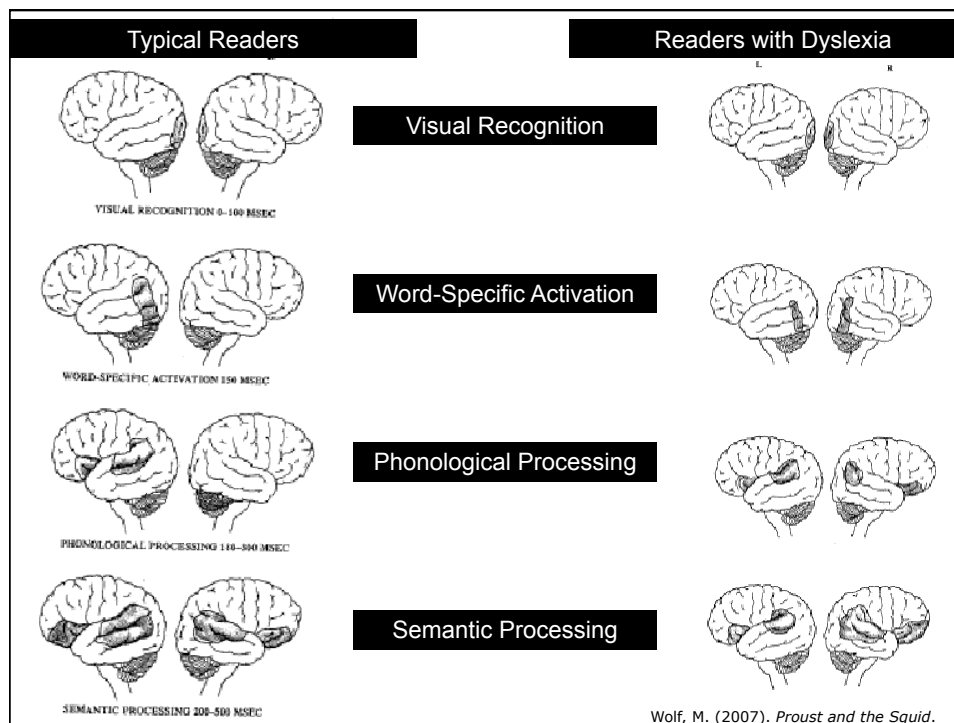
(Brunswick, 1999; Paulesu et al. 2001; Rumsey et al., 1992, 1997; Shaywitz et al., 1998, 2002; Simos, Breier, Fletcher, Bergman, & Papanicolaou, 2000; Simos, Papanicolaou, et al., 2000)



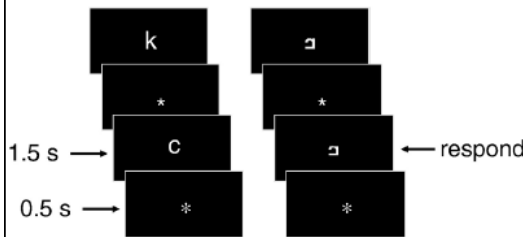
Compensatory Systems in Dyslexia

- Left and right hemisphere anterior regions
- Right hemisphere posterior regions
- Activations in right hemisphere negatively correlated with reading skills
- **Accurate, but not automatic, word reading**

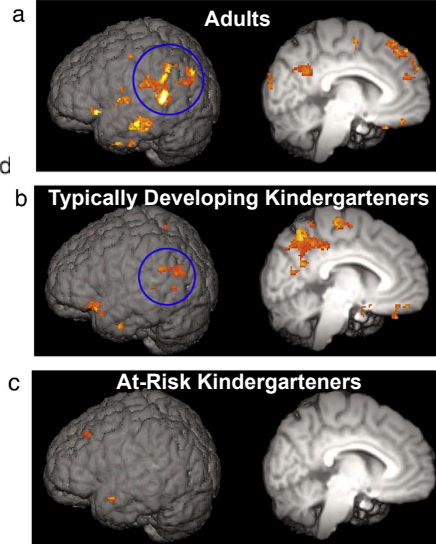
(Shaywitz et al., 2002)



Differences in Emerging Reading Systems



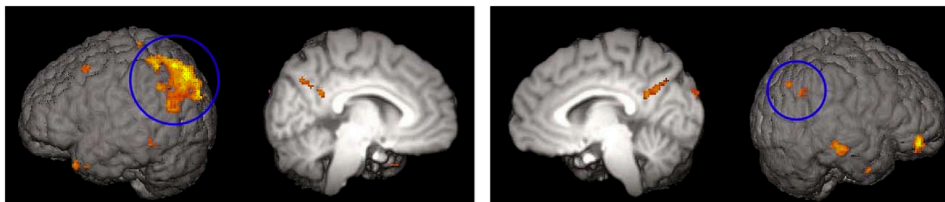
- Typically Developing Readers
 - initial recruitment and subsequent disengagement of right hemisphere
- At-Risk Developing Readers
 - compensatory recruitment of frontal regions



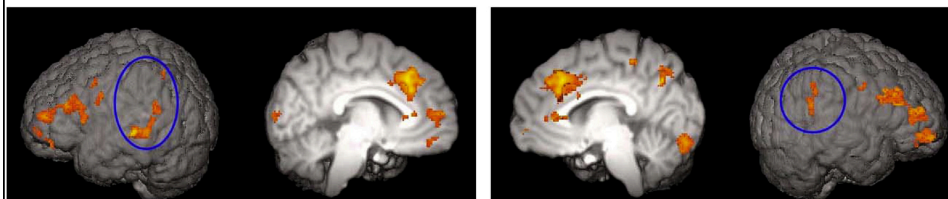
(Yamada et al., 2011)

Differences in Emerging Reading Systems

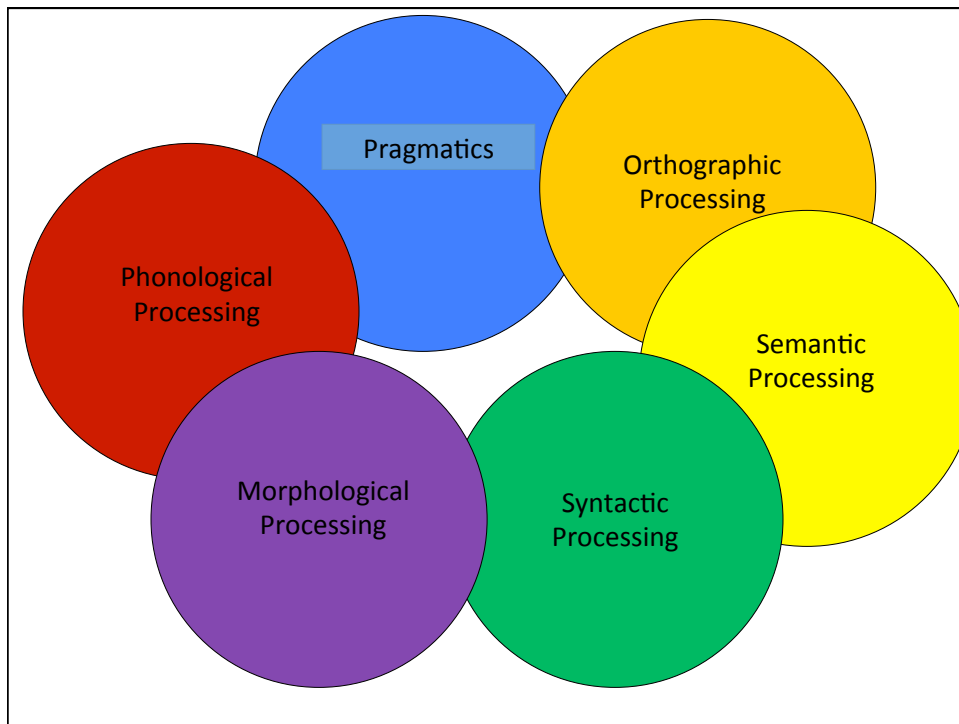
Typically Developing Kindergarten Readers after 3 months



At-Risk Kindergarten Readers after 3 months



(Yamada et al., 2011)



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