Developmental Dyslexia: Early Identification, Brain-correlates and Remediation Strategies

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Laboratories of Cognitive Neuroscience

www.childrenshospital.org/research-and-innovation/research-labs/gaab-laboratory
www.babymri.org
Overview

- Overview about the Brain
- The typical and atypical reading brain
- Remediating the reading brain
- The dyslexia paradox
- Early pre-markers of dyslexia before reading onset
- Compensatory mechanism and protective factors in DD
- Detecting children at risk for DD in infancy?
- Educational and Clinical Implications
Lobes & Directions

Superior

Anterior

Posterior

Left

Inferior
Brain Size: Is bigger better?

- Opossum
- Rabbit
- Cat

- Monkey
- Chimpanzee
- Man
Anatomical differences between musicians and non-musicians

Brain regions with gray matter differences between professional musicians, amateur musicians and nonmusicians.

Gaser, Schlaug; 2003. The Journal of Neuroscience
Plasticity in taxi drivers

Maguire et al., (2000)
Morphological changes induced by a short intervention

3 months training in juggling

Increased density of the grey matter in the jugglers compared to the non-juggler controls.

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GHOTI

“FISH”

- gh as in TOUGH
- o as in WOMEN
- ti as in NATION

George Bernard Shaw
Why learning to read is so difficult:

- Learning to read **in English** is particularly difficult. Some language systems are based on a system where each syllable represented a symbol (learn the symbols and you have mastered the system) or where the number of phonemes and graphemes are similar (e.g. Italian).

Examples:
- College
- Collegial
- Colleague
- **Ghost** versus **neighborhood**
Timeline of Reading development

- Sound and Language Processing
- Phonological Processing/Letter recognition
- Grapheme-morpheme Mapping/Single word/Connected text reading
- Connected text/Lexical Access/Comprehension
## Stages of Reading development

<table>
<thead>
<tr>
<th>Stage</th>
<th>Name</th>
<th>The Learner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 0: Birth to Grade 1</td>
<td>Emergent Literacy</td>
<td>Gains control of oral language; relies heavily on pictures in text; pretends to read; recognizes rhyme</td>
</tr>
<tr>
<td>Stage 1: Beginning Grade 1</td>
<td>Decoding</td>
<td>Grows aware of sound/symbol relationships; focuses on printed symbols; attempts to break code of print; uses decoding to figure out words</td>
</tr>
<tr>
<td>Stage 2: End of Grade 1 to End of Grade 3</td>
<td>Confirmation and Fluency</td>
<td>Develops fluency in reading; recognizes patterns in words; checks for meaning and sense; knows a stock of sight words</td>
</tr>
<tr>
<td>Stage 3: Grade 4 to Grade 8</td>
<td>Learning the New (Single Viewpoint)</td>
<td>Uses reading as a tool for learning; applies reading strategies; expands reading vocabulary; comprehends from a singular point of view</td>
</tr>
<tr>
<td>Stage 4: Secondary and Early Higher Education</td>
<td>Multiple Viewpoints</td>
<td>Analyzes what is read; reacts critically to texts; deals with layers of facts and concepts; comprehends from multiple points of view</td>
</tr>
<tr>
<td>Stage 5: Late Higher Education and Graduate School</td>
<td>A Worldview</td>
<td>Develops a well-rounded view of the world through reading</td>
</tr>
</tbody>
</table>

Source: Roskos et al., 2009.
Key predictors of reading ability before reading instruction starts:

- Phonological processing/Phonological awareness
- Speech perception
- Syntax production and comprehension
- Object naming
- Receptive/expressive vocabulary
- Rapid automatized naming abilities
- Letter name knowledge
- Verbal short-term memory

(e.g., Schatschneider et al., 2004; Georgiou et al., 2008; de Jong & van der Leij, 1999; Scarborough, 1998).
Home Literacy Environment (HLE)

Aspects of HLE that are most predictive of future language and literacy skills include (e.g., Hamilton, 2013; Payne, Whitehurst, & Angell, 1994; Bus et al., 1995):

- Age of onset of shared reading
- Frequency and quality of book reading
- Library visits
- Parent’s knowledge of storybook titles
- Maternal mediating style during shared reading
- Child’s perceived interest in reading
What is Developmental Dyslexia?

- Affects 5-17% of children.

- Specific learning disability characterized by
  - difficulties with speed and accuracy of word/text decoding
  - poor spelling and poor comprehension performance.

- Cognitive difficulties may further include speech perception, the accurate representation and manipulation of speech sounds, problems with language memory, rapid automatized naming or letter sound knowledge.

- Cannot be explained by poor vision or hearing, lack of motivation or educational opportunities.

- Familial occurrences as well as twin studies strongly support a genetic basis for DD.

- Currently up to seven theories that try to explain DD.

- No medications available.

- Strong psychological and clinical implications which start long before reading failure.
Psychological and Clinical Implications of DD

- Children with DD are often perceived by others as being ‘lazy’ or as those who ‘do not try enough.’

- Teachers, parents and peers often misinterpret the ‘dyslexic’ child’s struggle to learn as negative attitude or poor behavior and decreased self-esteem is often a result [Saracoglu et al., 1989; Riddick et al., 1999].

- These negative experiences leave children with DD vulnerable to feelings of shame failure, inadequacy, helplessness, depression and loneliness [e.g.; Valas et al., 1999].

- Possible anti-social behavior with long-standing consequences [Baker et al., 2007].

- Less likely that these children will complete high school [Marder et al., 1992] or join programs of higher education [Quinn et al., 2001], and increased probability that they will enter the juvenile justice system [Wagner et al., 1993].
Genetics

- Studies of families with DD suggest that DD is strongly heritable, occurring in up to 68% of identical twins and up to 50% of individuals who have a first degree relative with DD [Finucci et al., 1984; Volger et al., 1985].

- The genetic foundation of developmental disorders may be formed not by isolated genes, but rather by a combination of genes and the pathways that these genes regulate [Grigorenko, 2009].

- Several genes (e.g.; ROBO1, DCDC2, DYX1C1, KIAA0319) have been reported to be candidates for dyslexia susceptibility and it has been suggested that the majority of these genes plays a role in brain development. [e.g.; Galaburda et al., 2006; Hannula-Jouppi et al., 2005; Meng et al., 2005; Paracchini et al., 2006; Skiba et al., 2011].

- It has been hypothesized that DD may be the result of abnormal migration and maturation of neurons during early development [e.g.; Galaburda et al., 2006].
One word… (Poldrack & Halgren)
The typical reading network with its key components
A tentative pathway between a genetic effect, developmental brain changes and perceptual/cognitive deficits in DD has been proposed based on studies in animal and humans (Galaburda et al., 2006).

- Variant function in any number of genes involved in cortical development
- Subtle cortical malformation involving neuronal migration and axon growth
- Atypical cortico-cortical and cortico-thalamic circuits
- Atypical sensorimotor, perceptual and cognitive processes critical for learning (to read)
Several theories try to explain dyslexia:

- Impaired perceptual deficit (after Ramus, 2003)
- Deficient phonological representations
- Impaired reading
- Poor phonological skills

[after Ramus, 2003]
Structural and functional brain alterations in DD

(A) Gray matter (volumetric analyses)

[e.g. see Meta-analyses: Richlan et al., 2013; Linkerdoerfer et al., 2012, Martin et al., 20015]

(B) Gray matter (functional analyses)

Dys < Control

[e.g. see Meta-analyses: Richlan et al., 2011; Temple et al., 2002]
Structural brain differences (white matter): Typical and atypical readers

- DD has been associated with structural differences in left-hemispheric white matter organization as measured by Diffusion tensor imaging tractography [e.g., Klingberg et al., 2000; Rimrodt et al., 2010; Steinbrink et al., 2008].

- Most studies report alterations of the Arcuate Fasciculus, a neural pathway connecting the posterior part of the temporoparietal junction with the frontal cortex.

- Differences may reflect weakened white-matter connectivity among left-hemispheric areas that support reading. Measures (e.g.; fractional anisotropy) in left temporoparietal regions corelate positively with reading skills [e.g., Deutsch et al., 2005].
White matter alterations in DD

(C) White matter

- Left Superior Longitudinal Fasciculus
- Left Arcuate Fasciculus
- Left Inferior Frontal-Occipital Fasciculus
- Left Inferior Longitudinal Fasciculus
- Corpus Callosum
  (forceps minor - genu and major - splenium)
Variant function in any number of **Generalist genes**, such as COMT, VAL/MEL, FOXP2

**Dyslexia susceptibility genes**, such as ROBO1, DCDC2, DXYI1, KIAA0319
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Brain Changes After Remediation

Midway through the exam, Allen pulls out a bigger brain.
### Neural deficits in children with dyslexia ameliorated by behavioral remediation: Evidence from functional MRI

Elise Temple, Gayle K. Deutsch, Russell A. Poldrack, Steven L. Miller, Paula Tallal, Michael M. Merzenich, and John D. E. Gabrieli

**n = 45**

**Intervention:**
Fast ForWord (8 weeks)

<table>
<thead>
<tr>
<th>Reading: WJ-RMT</th>
<th>Dyslexic-reading children</th>
<th>Normal-reading children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretraining</td>
<td>Posttraining</td>
</tr>
<tr>
<td>Word ID</td>
<td>78.2 (56–95)</td>
<td>86.0 (72–99)</td>
</tr>
<tr>
<td>Word Attack</td>
<td>85.5 (72–102)</td>
<td>93.7 (82–109)</td>
</tr>
<tr>
<td>Passage Comp</td>
<td>83.3 (51–103)</td>
<td>88.9 (77–107)</td>
</tr>
<tr>
<td>Language: CELF-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptive</td>
<td>92.5 (69–120)</td>
<td>101.3 (75–122)</td>
</tr>
<tr>
<td>Expressive</td>
<td>95.0 (61–125)</td>
<td>102.2 (80–150)</td>
</tr>
<tr>
<td>Rapid Naming</td>
<td>79.1 (35–97)</td>
<td>86.5 (67–103)</td>
</tr>
</tbody>
</table>
Neural deficits in children with dyslexia ameliorated by behavioral remediation: Evidence from functional MRI

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Control

Frontal AND Temporo-parietal

Dyslexia

Frontal but NOT Temporo-parietal

Example:

B  D  = Rhyme
B  K  = Do Not Rhyme

n= 45
8 weeks intervention

[Temple et al. (2003) PNAS, 100]
Neural effect of intervention

Pre-Intervention

After training, metabolic brain activity in dyslexics more closely resembles that of typical readers.

Post-Intervention

Increased activity in Frontal AND Temporo-parietal

[Temple et al. (2003) PNAS, 100]
Neural Changes following Remediation in Adult Developmental Dyslexia

Guinevere F. Eden,1,* Karen M. Jones,1
Katherine Cappell,1 Lynn Gareau,1
Frank B. Wood,2 Thomas A. Zeffiro,1
Nicole A.E. Dietz,1 John A. Agnew,1
and D. Lynn Flowers1,2

n= 38
Intervention: Lindamood-Bell (8 weeks)

Sound deletion > word repetition

Post remediation > Pre-remediation
# Neuroimaging of Reading Intervention: A Systematic Review and Activation Likelihood Estimate Meta-Analysis

Laura A. Barquero¹, Nicole Davis¹,²,³,⁴, Laurie E. Cutting¹,²,³,⁴,⁵

<table>
<thead>
<tr>
<th>Study</th>
<th>RD N</th>
<th>CT N</th>
<th>Age</th>
<th>Intervention</th>
<th>Dosage</th>
<th>Intervention consisted of sight word reading, letter sound practice, decoding practice, and reading for fluency.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simon et al., 2006</td>
<td>6, 6 received Phonographix</td>
<td>6</td>
<td>7-12 yrs</td>
<td>Phonographix Read America, Sound Journal Phonemic Sequencing, Lindamore Phonics, San Luis Obispo, CA</td>
<td>80 hrs. 5-12 h/day over 8 weeks</td>
<td></td>
</tr>
<tr>
<td>Ashard et al., 2003</td>
<td>10</td>
<td>11</td>
<td>139.1 (98.8), months, 13.4 (7.9) months</td>
<td>Instruction in linguistic awareness, alphabetic principle, fluency, and reading comprehension</td>
<td>28 hrs. 2h/day over 14 session days (3 wks)</td>
<td></td>
</tr>
<tr>
<td>Temple et al., 2003</td>
<td>20</td>
<td>22</td>
<td>8-12 yrs</td>
<td>Fast Forword Language (Scientific Learning, Co., Oakland, CA)</td>
<td>100 min/day, 5 days/wk, average 27.5 days</td>
<td></td>
</tr>
<tr>
<td>Eden et al., 2004</td>
<td>19 total, 10 received intervention</td>
<td>19</td>
<td>adults, RD 44.0 (9.4), CT 41.9 (6.7)</td>
<td>Multisensory instruction including sound awareness, letter-sound association, auditory feedback administered by Lindamore Bell Learning Corporation staff</td>
<td>5 hrs/day, 8 wks, avg 112.3 hr total</td>
<td></td>
</tr>
<tr>
<td>Skaggs et al., 2004</td>
<td>40 total, 17 received experimental intervention, 12 received community intervention</td>
<td>28</td>
<td>6.4-9.4 yrs, 5-10 yrs</td>
<td>Experimental intervention (12) included sound symbolic associations, blending, timed reading for fluency, and reading, dictation</td>
<td>50 min/day for 8 months</td>
<td></td>
</tr>
<tr>
<td>Simon et al., 2005</td>
<td>16, 18 responders, 8 non-responders</td>
<td>17</td>
<td>6.6-7.2 yrs at baseline (Low Risk group 5.6-6.5, High Risk Group 6.5-7.2)</td>
<td>Pragmatic Reading and Responsive Reading (128)</td>
<td>40 min/day, 5 days/wk for 8 months</td>
<td></td>
</tr>
<tr>
<td>Richard et al., 2006</td>
<td>6 total, 8 non-responders</td>
<td>21</td>
<td>RD 133.8 months, CT 132.6 months</td>
<td>Instruction in alphabetic principle, composition and other orthographic spelling treatment or morphological spelling treatment</td>
<td>28 hr total 2 h/day for 14 sessions over 3 weeks</td>
<td></td>
</tr>
<tr>
<td>Hottel et al., 2007</td>
<td>54 struggling readers identified by teachers, many had scores in average range</td>
<td>10.0 (1.09) yrs</td>
<td>PowerKidz Reading Initiative. Many participants received 1 of 4 interventions, but there was no significant effect of intervention on decoding scores</td>
<td>PowerKidz project used four programs: Corrective Reading, Wilson Reading, Spelling Road Phonological Auditory Training (PAT), Failure Free Reading</td>
<td>about 5 months during school year</td>
<td></td>
</tr>
<tr>
<td>Richard et al., 2007</td>
<td>20 total, 11 phonological treatment, 9 non-phonological treatment</td>
<td>12</td>
<td>RD phonological 137.7 (100) months, RD non-phonological 134.60 (110) months, CT 126.60 (88) months</td>
<td>Phonological treatment included explicit written language instruction using phonological working memory, phoneme-phoneme correspondences in spelling, and science report writing (325)</td>
<td>24 hrs total—8 sessions over 2 wks with 3 hr/session</td>
<td></td>
</tr>
<tr>
<td>Simon et al., 2007</td>
<td>15</td>
<td>7-9 years</td>
<td>Phonographix (131) and Read Naturally (132)</td>
<td>16 weeks total 2 h/day for 8 wks Phonographix, 1 hr/day for 8 wks Read Naturally</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simon et al., 2008</td>
<td>15, 8 responders, 7 non-responders</td>
<td>10</td>
<td>7-9 years</td>
<td>Phonographix (131) and Read Naturally (132)</td>
<td>16 weeks total 2 h/day for 8 wks Phonographix, 1 hr/day for 8 wks Read Naturally</td>
<td></td>
</tr>
<tr>
<td>Melder et al., 2008</td>
<td>23 (possible overlap with Hottel et al, 2007)</td>
<td>12</td>
<td>5th grade</td>
<td>PowerKidz project used four programs: Corrective Reading, Wilson Reading, Spelling Road Phonological Auditory Training (PAT), Failure Free Reading</td>
<td>100 hrs total over 6 months</td>
<td></td>
</tr>
<tr>
<td>Odegard et al., 2008</td>
<td>12 total 6 responders, 6 non-responders</td>
<td>6</td>
<td>10-14 yrs</td>
<td>Take Flight: A comprehensive intervention for students with dyslexia (133)</td>
<td>90 min/day, 4 days/wk for 2 school years</td>
<td></td>
</tr>
<tr>
<td>Richards &amp; Bremner, 2006</td>
<td>18 (same as Richards et al., 2006)</td>
<td>21</td>
<td>RD 133.8 months, CT 132.6 months</td>
<td>Instruction in alphabetic principle, composition, and other orthographic spelling treatment or morphological spelling treatment</td>
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The ‘Dyslexia Paradox’

- Typically, dyslexia is not diagnosed until a child has failed to learn to read as expected, usually in third grade or later. As a result, children with dyslexia must often make up a large gap in reading ability and experience to reach the level of their typically reading peers (e.g., Hiebert & Taylor, 2000).

- A meta-analysis comparing intervention studies offering at least 100 sessions, reported larger effect sizes for intervention studies conducted with kindergarten and first graders than with children in 2nd and 3rd grades (Wanzek & Vaughn, 2007).

- When “at risk” beginning readers receive intensive instruction, 56% to 92% of at-risk children across six studies reached the range of average reading ability [Torgesen, 2004].
The dyslexia paradox

Window for most effective intervention

Typical window for a Dyslexia Diagnosis
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The Boston Longitudinal Dyslexia Study (BOLD)

Early Identification
- children at-risk

Diagnosis
- Dyslexia

Follow up:
- prior to first grade
- prior to second grade
- prior to third grade

- Functional MRI
- Structural MRI
- Behavioral tests
- Psychophysics
- Questionnaires
- DNA

To date 114 children enrolled longitudinally (64 FHD+/50 FHD-).

Pre-readers (Word ID <5), reading instruction within next year.
Tasks within MRI scanner:
- Phonological Processing
- Rapid auditory processing
- Executive functioning
- Reading Fluency

Psychometric Measures:
- Clinical Evaluation Language Fundamentals – Preschool 2
- Comprehensive Test Of Phonological Processing
- Grammar And Phonology Screening Test
- York Assessment for Reading for Comprehension
- Rapid Automatized Naming and Rapid Alternating Stimulus Test
- Kaufman Brief Intelligence Test 2
- Year 2: Word reading (timed/untimed), passage comprehension, fluency, spelling, letter knowledge

Psychophysics Measures:
- RAP (tones and environmental sounds)
- Rise Time perception

Questionnaires:
- Development
- Home literacy
- SES

Structural brain differences
(gray matter, DTI)
Control task: Voice matching
<table>
<thead>
<tr>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(prereading status)</td>
<td>(beginning readers)</td>
<td></td>
</tr>
<tr>
<td><em>Significant differences in:</em></td>
<td><em>Significant differences in:</em></td>
<td><em>Significant differences in:</em></td>
</tr>
<tr>
<td>Expressive and receptive language/content</td>
<td>Expressive language/Language content</td>
<td>Core and receptive Language</td>
</tr>
<tr>
<td>Phonological processing</td>
<td>Phonological processing</td>
<td></td>
</tr>
<tr>
<td>Rapid automatized naming</td>
<td>Rapid automatized naming</td>
<td>Rapid automatized naming</td>
</tr>
<tr>
<td>Rapid auditory Processing</td>
<td>Letter knowledge</td>
<td></td>
</tr>
<tr>
<td>Single word reading (timed/untimed)</td>
<td>Passage comprehension</td>
<td>Single word reading (timed/untimed)</td>
</tr>
<tr>
<td>Spelling</td>
<td></td>
<td>Passage comprehension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spelling</td>
</tr>
<tr>
<td><em>No differences in:</em></td>
<td></td>
<td>Reading Fluency</td>
</tr>
<tr>
<td>IQ, age, Home Literacy, SES</td>
<td></td>
<td><em>all p&lt;0.05</em></td>
</tr>
<tr>
<td><em>all p&lt;0.05</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Functional characteristics of developmental dyslexia in left-hemispheric posterior brain regions predate reading onset

Nora Maria Raschle\textsuperscript{a,b}, Jennifer Zuk\textsuperscript{a}, and Nadine Gaab\textsuperscript{a,b,c,1}

[Raschle et al., PNAS 2012]
Structural brain alterations associated with dyslexia predate reading onset

Nora Maria Raschle, Maria Chang, Nadine Gaab

[Raschle et al., Neuroimage 2010]
Longitudinal data (before and after reading onset) in subsequent good and poor readers

Subsequent Good > Subsequent Poor Reader

Subsequent Good > Subsequent Poor Reader

p < 0.001 & p < 0.005

[Raschle et al., in prep]
Tract Profiles of White Matter Properties: Automating Fiber-Tract Quantification

Jason D. Yeatman¹,², Robert F. Dougherty², Nathaniel J. Myall³, Brian A. Wandell¹,², Heidi M. Feldman³,⁴

¹ Department of Psychology, Stanford University, Stanford, California, United States of America, ² Stanford Center for Cognitive and Neurobiological Imaging, Stanford University, Stanford, California, United States of America, ³ Stanford University School of Medicine, Stanford, California, United States of America, ⁴ Division of Neonatal and Developmental Medicine, Department of Pediatrics, Stanford University School of Medicine, Stanford, California, United States of America

Tract Diffusion Profile

FA-value

location on the tract
Development of the AF (Cross-sectional) 

Preschool (A1)

Kindergarten/1st/2nd grade (A2)

3rd/4th/5th grade (A3)

n = 78
112 scans included

Wang et al., under review
Linking FA development and reading development

Wang et al., under review
Sulcal pattern (global pattern of arrangement, number and size of sulcal segments) has been hypothesized to relate to optimal organization of cortical function and white matter connectivity (Van Essen, 1997; Klyachko and Stevens, 2003; O’Leary et al., 2007; Fischl et al., 2008).

Individuals with DD may undergo atypical sulcal development. Moreover, global sulcal pattern is determined during prenatal development and may therefore better reflect genetic brain development (Rakic, 2004; Kostovic and Vasung, 2009).
Four groups:
1. Beginning readers FHD-
2. Beginning readers FHD+
3. Developmental Dyslexia
4. Typical developing children

- The pattern of sulcal basin area in the left parieto-temporal and occipito-temporal regions was significantly atypical in children with DD compared to controls.

- Significantly atypical sulcal area pattern was also confirmed in kindergarteners with a familial risk of DD compared to controls.

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Im et al., in 2015
The READ Study
(Researching Early Attributes of Dyslexia)


- Invited children with and without risk for dyslexia to participate in a follow-up study including brain imaging with MRI and EEG (n = 180 for EEG and n = 160 for MRI).

- Following these children to see which measures from kindergarten best predict reading ability at the end of 1st and 2nd grade.
READ at a Glance

- 21 schools: inner-city charter schools, private, suburban district-run schools, and Archdiocese schools
- Free/reduced lunch eligibility from 0% to 80%
- Ethnically diverse student population (49% minority)
- Teacher professional developments and parent presentations conducted in all schools
- Brain awareness days conducted in various schools

“We very much enjoyed everything you and your staff provided. You are warm and professional and certainly put your subjects at ease...It’s exciting to see such cutting-edge research from the inside out!”  
(Parent, Wheeler School)

“...They were excellent presenters. The students had a wonderful time and were very engaged in the activities.” (Teacher, Lowell Elementary)

“Your whole team was terrific in making the afternoons lots of fun and educational” (Parent, Hosmer Elementary)
### Key Assessments

<table>
<thead>
<tr>
<th>Kindergarten</th>
<th>1st Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phonological Awareness (CTOPP)</strong></td>
<td><strong>Reading (GORT-5)</strong></td>
</tr>
<tr>
<td>- Elision</td>
<td></td>
</tr>
<tr>
<td>- Blending</td>
<td></td>
</tr>
<tr>
<td><strong>Rapid Automatized Naming (RAN/RAS Tests)</strong></td>
<td></td>
</tr>
<tr>
<td>- Objects</td>
<td></td>
</tr>
<tr>
<td>- Colors</td>
<td></td>
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<tr>
<td>- Letters</td>
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</tr>
<tr>
<td><strong>Letter and Word ID (WRMT-3)</strong></td>
<td></td>
</tr>
<tr>
<td>- Letter ID</td>
<td></td>
</tr>
<tr>
<td>- Word ID</td>
<td></td>
</tr>
<tr>
<td>- Letter sound (YARC)</td>
<td></td>
</tr>
</tbody>
</table>
Six Distinct Cognitive Profiles of Early Reading

Ozernov-Palchik et al., in prep
Project READ

Brain Imaging and Longitudinal Follow-up

- 186 children total, 115 with risk for dyslexia
  - 31% low phonological awareness
  - 28% low letter knowledge
  - 38% low RAN scores
  - 15% with family history of dyslexia
Tracking the Roots of Reading Ability: White Matter Volume and Integrity Correlate with Phonological Awareness in Prereading and Early-Reading Kindergarten Children

Zeynep M. Saygin,1* Elizabeth S. Norton,1* David E. Osher,1 Sara D. Beach,1 Abigail B. Cyr,1 Ola Ozernov-Palchik,3 Anastasia Yendiki,4 Bruce Fischl,2,4 Nadine Gaab,3 and John D.E. Gabrieli1

The Journal of Neuroscience, August 14, 2013 • 33(33):13251–13258 • 13251

a. $r = 0.38, P = 0.015$

Blending Words Raw Score

BW score=0  BW score=3  BW score=9  BW score=11
Overview

- Overview about the Brain
- The typical and atypical reading brain
- Remediating the reading brain
- The dyslexia paradox
- Early pre-markers of dyslexia before reading onset
- Compensatory mechanism and protective factors in DD
- Detecting children at risk for DD in infancy?
- Educational and Clinical Implications
Why do some kids improve and others don’t?

- Some children do compensate and some don’t
- What is the brain basis of compensation?
  - more like typical development?
  - Alternative pathway(s)?

Who does compensate?
Protective factors and compensatory mechanisms in typical readers with familial risks

- Protective environmental variables (e.g., home literacy, teaching efficiency etc.)
- Proactive cognitive abilities (e.g., high IQ, high vocabulary etc.)
- Genetics
- Compensatory neural mechanisms (e.g., increased involvement of the right hemisphere etc.)

Dys > Control

- Left Precentral Gyrus
- Right Inferior Frontal Gyrus
Brain measures predicted with 92% accuracy which individual children improved and which individual children did not improve 2.5 years later.
Compensatory effects prior to reading onset?

Of 21 FHD+ children, 11 developed into good readers, while 10 developed into poor readers. The subsequent good readers show higher FA development rates in right SLF. 

Wang et al., under review
Multivariate pattern analysis:

A searchlight technique was applied to look for regions that showed distinctive patterns between FHD+ and FHD- children with subsequent good reading skills.
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<table>
<thead>
<tr>
<th>Demographics</th>
<th>FHD-</th>
<th>FHD+</th>
<th>T-test 2-tailed</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>18</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Age (days)</td>
<td>297.78 ± 99.13</td>
<td>332.64 ± 117.91</td>
<td>p &gt; .100</td>
</tr>
<tr>
<td>Expressive Mullen T-score</td>
<td>48.67 ± 4.77</td>
<td>47.90 ± 10.87</td>
<td>p &gt; .100</td>
</tr>
</tbody>
</table>
Tract Profiles of White Matter Properties: Automating Fiber-Tract Quantification

Jason D. Yeatman\textsuperscript{1,2*}, Robert F. Dougherty\textsuperscript{2}, Nathaniel J. Myall\textsuperscript{3}, Brian A. Wandell\textsuperscript{1,2}, Heidi M. Feldman\textsuperscript{3,4}

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Tract Diffusion Profile

location on the tract
[A] FA values in FHD+ and FHD- infants at each of the 50 nodes.  
[B] FHD+ infants exhibit significantly lower FA values compared to FHD- infants in red regions (all $p < 0.02$, controlled for multiple comparisons)

**Multivariate pattern analysis (MVPA):**  
MVPA (using FA at each node of the left AF as input) was performed to determine whether FA can distinguish FHD+ and FHD- infants  
- 82% prediction accuracy ($p = 0.001$)
FA values correlate with Expressive Language Scores

\[ R = 0.481 \]
\[ p = 0.037 \]

Langer et al., in press
Atypical development of AF from infancy to late elementary school?
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Educational and Clinical Implications

- Early identification may reduce the clinical, psychological and social implications of DD.

- Development and implementation of early and customized remediation programs (who should get which intervention) → Subtyping and early customized remediation

- Informing (early) diagnostic guidelines

- Changes in educational policies (early IEPs; design and implementation of customized curriculums for children at-risk).

- Evaluation and improvement of existing remediation programs will likely prove cost-efficient as programs are made more effective.

- Which brain will benefit from which schooling/teaching style?

- Can we determine if someone is ready for schooling based on their brain?

- Improved psycho-social development (reduced child stress, parental stress, improved overall family dynamic).

- Maximizing use of ‘intellectual potential’.

- Most importantly, maximizing the joy to learn to read.
11 Common Myths about Dyslexia

- Dyslexia is a visual problem.
- If you perform well in school, you cannot have dyslexia.
- Smart people can’t be dyslexic, if you have dyslexia you cannot be very smart.
- People who have dyslexia are unable to read.
- There are no clues to dyslexia before a child enters school.
- Dyslexia mainly affects boys.
- Dyslexics are ‘gifted’ / ‘stupid’.
- Dyslexia disappears with age / can be outgrown.
- Dyslexia is rare.
- Dyslexics will not succeed in life.
- Dyslexia can be cured or helped by special balancing exercises, fish-oils, glasses with tinted lenses, vision exercises, NLP magical spelling, modeling clay letters, inner-ear-improving medications, training primitive reflexes, eye occlusion (patching), etc.
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April Benasich, Rutgers University
Sandra/Joseph Jacobson, Wayne State
Gennaro Chierchia, Harvard University
Autism Excellence Center
Maryanne Wolf, Tufts University
Paulo Andrade, São Paulo
Georgio Sideridis, BCH

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Barbara Peysakhovic (RA, BOLD + Infants)
Danielle Sliva (RA, BOLD + Infants)
Michelle Lee (Psychometric Assessments)
Sarah Beach (RA, READ)
Abby Cyr (RA, READ)
Zeynep Saygin (READ)

MRI Team, Children’s Hospital Boston & MIT

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- Grammy Foundation
- William Randolph Hearst Foundation (Infants)
- Children’s Hospital Boston Pilot Award (BOLD)
- Developmental Medicine Center Young investigator Award
- Victory Foundation

www.childrenshospital.org/research-and-innovation/research-labs/gaab-laboratory
www.babymri.org
The Typical and Atypical Reading Brain

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Developmental Medicine Center
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www.childrenshospital.org/research-and-innovation/research-labs/gaab-laboratory
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