Atypical Language and Reading Development

H-126 Typical and Atypical Neurodevelopment
October 16th, 2017

Overview

- Atypical language development
- Neurobiology of atypical language development
- Atypical reading development/Developmental Dyslexia
- Theories of Developmental Dyslexia
- Neurobiology of atypical reading development
- Remediating the atypical reading brain
- Early identification of children at risk for reading impairments
- Mandatory screening for dyslexia?
- Challenges and implications for educational practice and policy

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Developmental disorders of speech

- Occur in approx. 7-10% of children who have no deficits in hearing, intelligence, or socioemotional stimulation.
- Twin studies show high heritability, especially for expressive language impairment (with and without articulation problems).

[Heritability is the proportion of observed variation in a particular trait (such as height) that can be explained by inherited genetic factors in contrast to environmental factors (e.g., nutrition, health care)].

TABLE 10.7	Important Milestones in Language Development				
Age (years)	**Phonology**	**Semantics**	**Morphology/syntax**	**Pragmatics**	**Metalinguistic awareness**
0–1	Receptivity to speech and discrimination of speech sounds Babbling begins to resemble the sounds of native language	Some interpretation of intonational cues in others' speech Preverbal gestures appear Vocables appear Little if any understanding of individual words	Preference for phrase structure and stress patterns of native language	Joint attention with caregiver to objects and events Turn-taking in games and vocalizations Appearance of preverbal gestures	None
1–2	Appearance of strategies to simplify word pronunciations	First words appear Rapid expansion of vocabulary after age 18 months Overextensions and underextensions of word meanings	Holophrases give way to two-word telegraphic speech Sentences express distinct semantic relations Acquisition of some grammatical morphemes	Use of gestures and intonational cues to clarify messages Richer understanding of vocal turn-taking rules First signs of etiquette in children's speech	None
3–5	Pronunciations improve	Vocabulary expands Understanding of spatial relations and use of spatial words in speech	Grammatical morphemes added in regular sequence Awareness of most rules of transformational grammar	Beginning understanding of illocutionary intent Some adjustment of speech to different audiences Some attempts at clarifying obviously ambiguous messages	Some phonemic and grammatical awareness
6–adolescence	Pronunciations become adultlike	Dramatic expansion of vocabulary, including abstract words during adolescence Appearance and refinement of semantic integrations	Acquisition of morphological knowledge Correction of earlier grammatical errors Acquisition of complex syntactical rules	Referential communication improves, especially the ability to detect and repair uninformative messages one sends and receives	Metalinguistic awareness blossoms and becomes more extensive with age

Table 10.7 Important Milestones in Language Development.

Developmental Psychology: Childhood & Adolescence: Childhood and Adolescence, by David David Reed Shaffer & Katherine Kipp.

Oral Language Component	Definition	Common Difficulties	Common Diagnosis
Phonology	The sound system of language	• Errors in speech production • Poor phonological/phonemic awareness	• Speech sound disorders (articulation disorder, childhood apraxia of speech, speech delay) • Receptive/Expressive language impairment • Articulation disorder • Developmental verbal dyspraxia
Morphology and Syntax	The rues used to describe the structure of language	• Errors in marking grammatical tense • Errors in complex grammar (e.g. wh-questions, passive construction)	• Specific language impairment (SLI or (Grammatical) G-SLI) • Receptive/Expressive language impairment
Semantics/ Lexicon	The meaning of a word/ Vocabulary	• Delayed word/phrase acquisition • Limited vocabulary	• Late talkers • Language delay • Receptive/Expressive language impairment • Semantic language disorder
Pragmatics	How people use language to communicate in socially appropriate ways	• Difficulties with using language appropriately (e.g., persuade, request, inform, reject), adapt language (e.g., talk differently to different audiences, provide background information to unfamiliar listeners); follow conversational rules (e.g., take conversational turns, introduce conversation topics, rephrase sentences, maintain appropriate physical distance during conversational exchanges, use appropriate facial expressions and frequent (not too frequent)eye contact, etc) • Difficulties understanding abstract language or idioms, metaphor, etc.	• (Social) Pragmatic language disorder • Nonverbal language disability • Autism spectrum • Aspergers syndrome

(Zuk & Gaab, unpublished)

Some examples

- https://www.youtube.com/watch?v=UmLu8rzbHhE
- https://www.youtube.com/watch?v=tvqSnjyPKw0

Example of SLI speech (age 4:3)

Adult:	*Ok, ready?*
Child:	*Ready.*
Adult:	*This is Jim. Tell me a story about Jim.*
Child:	*Him going fishing. Jim hold . . . water. And go fish. And [unclear]*
Adult:	*I didn't hear this [last] one.*
Child:	*I don't know.*
Adult:	*Ok. How many more do you think we have?*
Child:	*I don't know.*
Adult:	*Ok, ready?*
Child:	*Ready.*
Adult:	*This is Kathy. Tell me a story.*
Child:	*Kathy brush teeth. Her eat. And her get clothes on.*

SLI diagnosis (Leonard, 1998)

Table 1.1
Criteria for SLI

Factor	Criterion
Language ability	Language test scores of −1.25 standard deviations or lower; at risk for social devalue
Nonverbal IQ	Performance IQ of 85 or higher
Hearing	Pass screening at conventional levels
Otitis media with effusion	No recent episodes
Neurological dysfunction	No evidence of seizure disorders, cerebral palsy, brain lesions; not under medication for control of seizures
Oral structure	No structural anomalies
Oral motor function	Pass screening using developmentally appropriate items
Physical and social interactions	No symptoms of impaired reciprocal social interaction or restriction of activities

Speech sound disorder: Examples

Examples of speech errors:

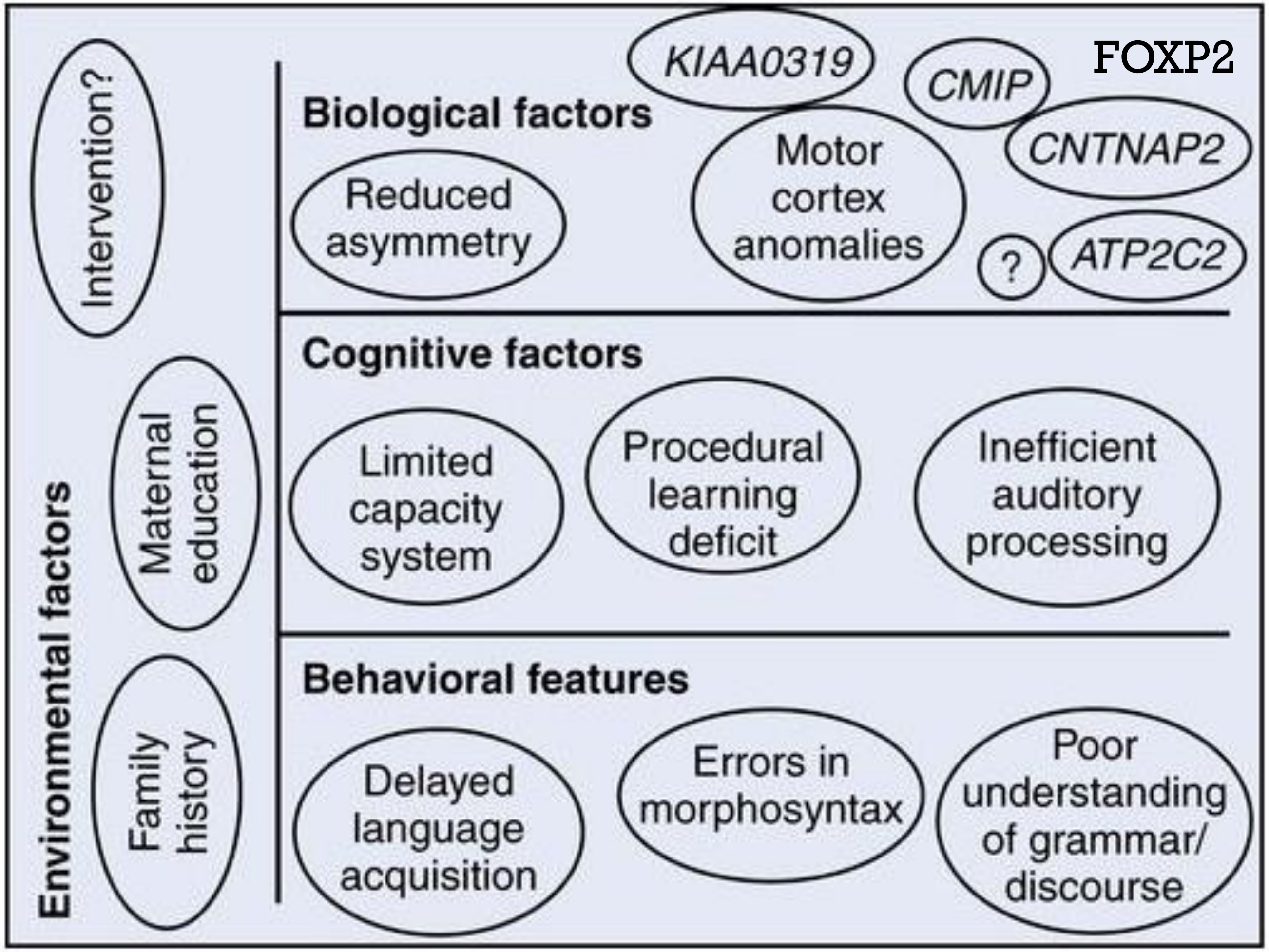
Target	Production
Who did the cat wash?	*Who did the **cash** wash?*
The cat with the bell is happy.	*The **tat wif** the bell is happy.*
The cat is gray.	*The **tat** is **gway.***
Which dog did the cat push?	***Whits** dog did the **ca- pus**?*

Examples:
https://www.youtube.com/watch?v=_5ph53B9UXY

https://www.youtube.com/watch?v=2huFf48keXk

(READ study; Jenny Zuk)

Environmental and genetic factors of language disorders



(Modified after Rhea Paul: Language Disorders)

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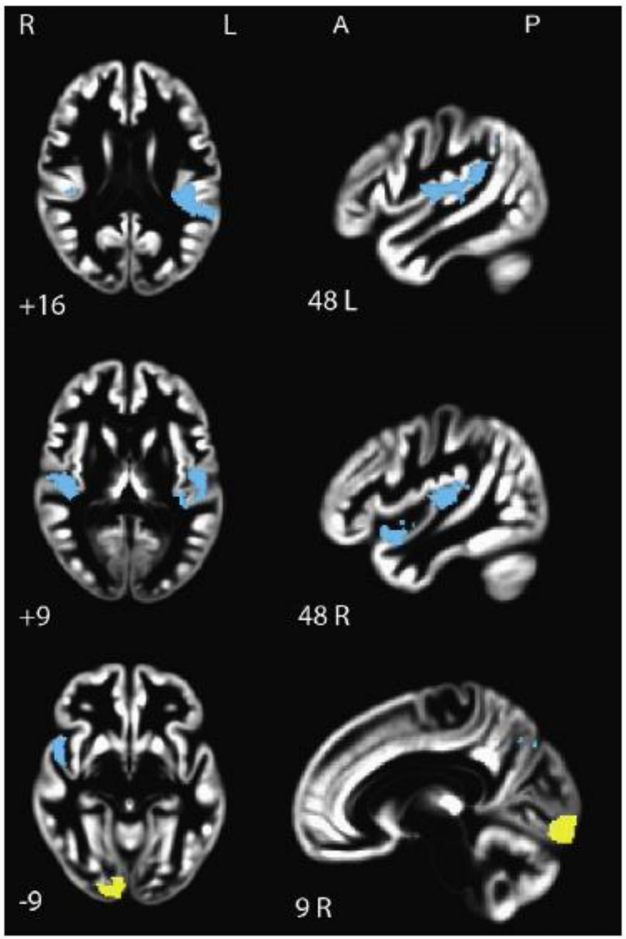
Structural brain differences in school-age children with residual speech sound errors

Jonathan L. Preston [a,b,*], Peter J. Molfese [a], W. Einar Mencl [a], Stephen J. Frost [a], Fumiko Hoeft [a,c], Robert K. Fulbright [a,d], Nicole Landi [a,e], Elena L. Grigorenko [e], Ayumi Seki [a,f], Susan Felsenfeld [a], Kenneth R. Pugh [a,d,g,h]

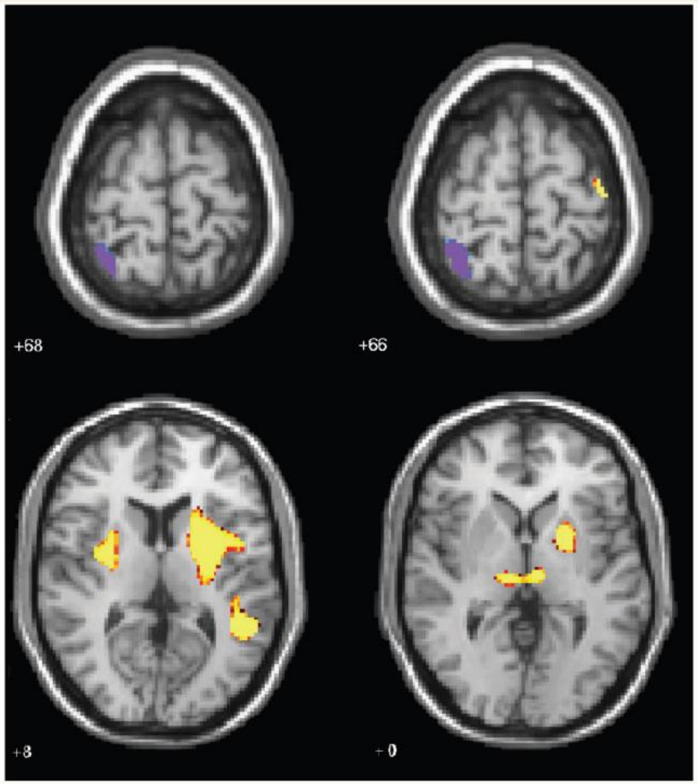


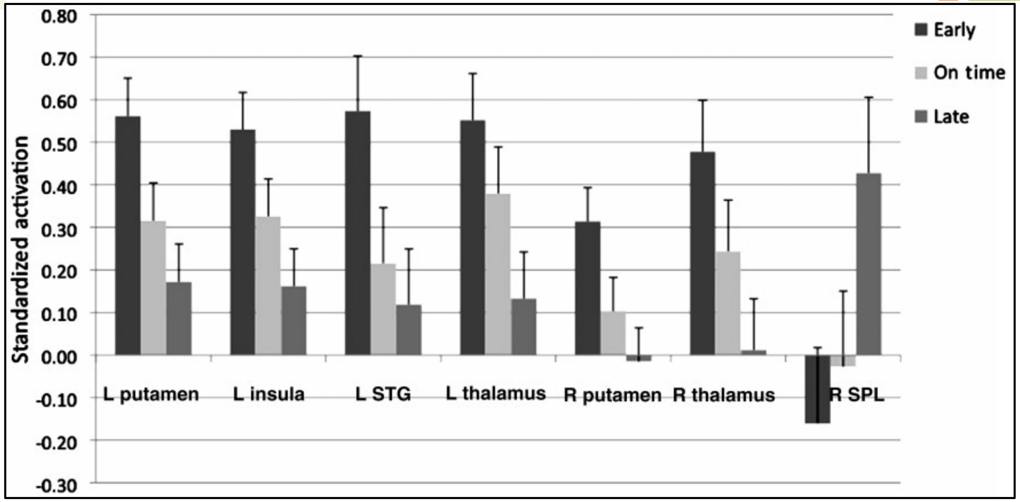
Greater gray matter volume indices in children with speech sound disorder in bilateral superior temporal gyrus

→ delays in neuronal pruning in critical speech regions or differences?

Early and late talkers: school-age language, literacy and neurolinguistic differences

Jonathan L. Preston,[1] Stephen J. Frost,[1] William Einar Mencl,[1] Robert K. Fulbright,[1,2]
Nicole Landi,[1,3] Elena Grigorenko,[3] Leslie Jacobsen[1] and Kenneth R. Pugh[1,4]

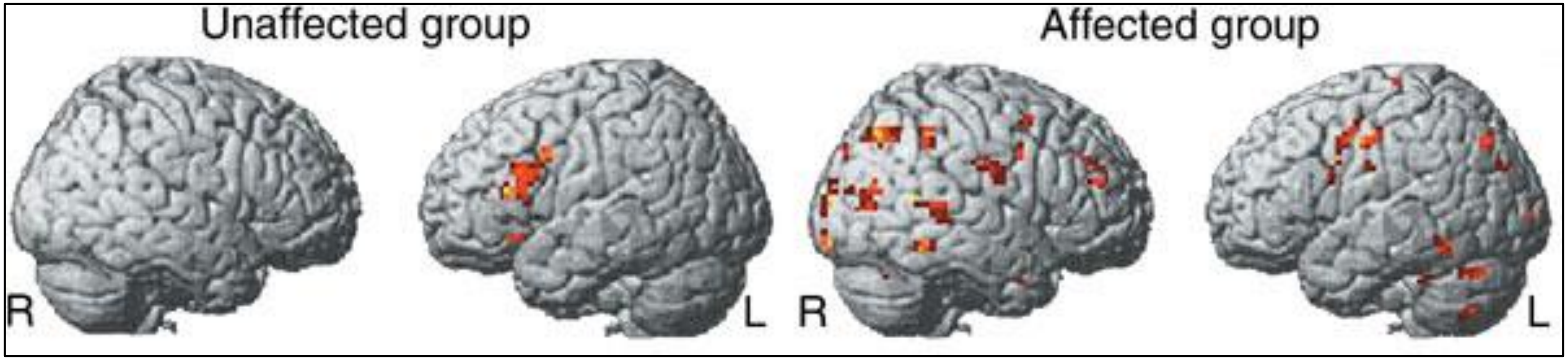




Age of functional language acquisition can have long-reaching effects on reading and language behavior, and on the corresponding neurocircuitry that supports linguistic function into the school-age years.

The KE family

- Three-generation KE family, half of whose members are affected by a developmental verbal dyspraxia
- First family with speech disorder to be investigated using genetic analyses.
- Genetic mutation discovered: FOXP2 ("language gene")
- Unique opportunity to identify the brain abnormalities associated with their particular form of impairment: expressive language deficit accompanied by an articulation disorder



Overt language task > rest

Liégeois et al., 2003

Risk and Protective Factors for Late Talking

- Prospective, longitudinal pregnancy cohort of 1023 mothers in Calgary, Canada
- Prevalence of late talking: 12.6%
- Risk factors: Male sex, family history of late talking/diagnosed speech or language delay
- Protective factors: Engagement in informal play opportunities, daily reading activity, attendance child care centers.
- Biological and environmental factors were associated with the development of late talking. Biological factors placed toddlers at risk for late talking, and various aspects of the environment seem to play a protective role.

Collisson et al., 2016

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The development of basic reading skills is one of the primary goals of elementary education…but

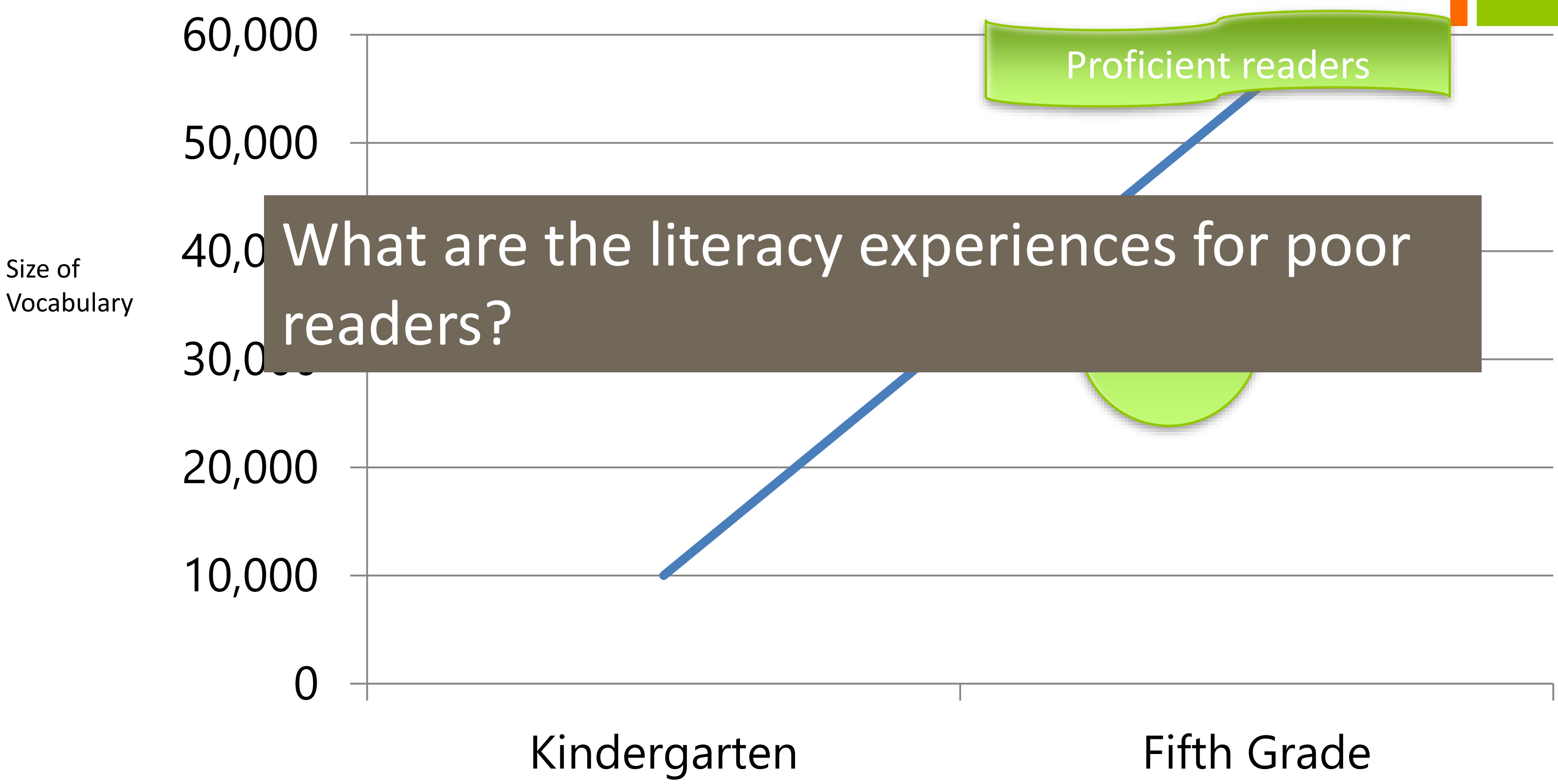
- 66% of U.S. fourth graders are not reading at grade level
- Among students from low socio-economic backgrounds, 80% are reading below grade level
- The US Department of Labor estimates that illiteracy costs American businesses about $225 billion a year in lost productivity.

e.g., National Center for Education Statistics (2013). The Nation's Report Card: A First Look: 2013 Mathematics and Reading (NCES 2014-451). Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

Percentage of below average readers in 1^{st} grade who were below average readers in 9^{th} grade. (de Jong & van der Leij, 2003; Juel, 1988; Landerlamp & Wimmer, 2008; Lundberg, 1994)

[*Slide: Melissa Orkin*]

How does Reading Improve Learning?



What are the literacy experiences for poor readers?

(Biemiller, 2005; Moats, 2001)

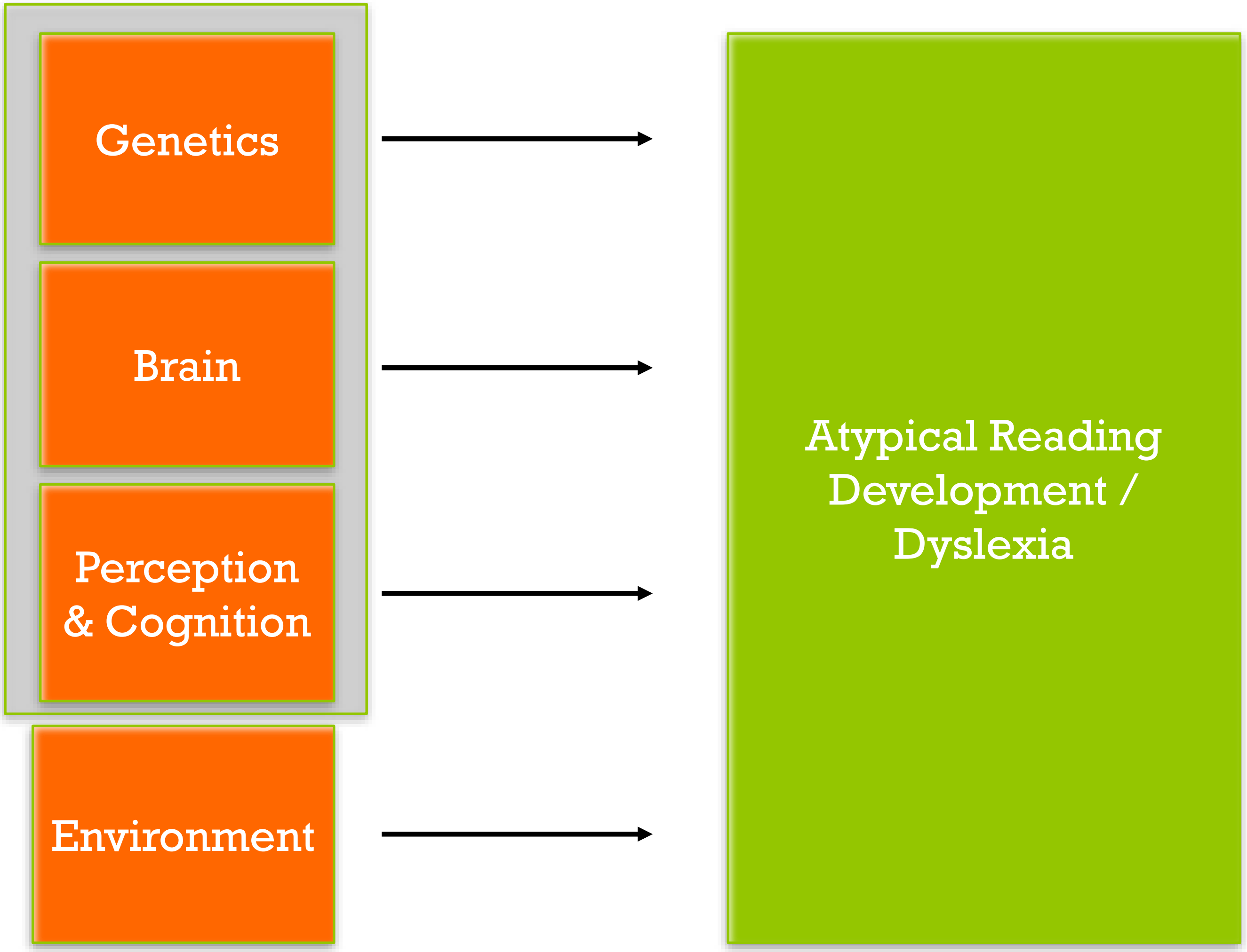
The Matthew Effect

Good **Poor**

“Students at 90th percentile may read as many words in two days as a child at the 10th percentile reads in an entire year outside of school.” Torgesen, 2004

(Cain & Oakhill, 2011;
Wigfield & Guthrie, 1997)

Factors contributing to atypical reading development



What is Developmental Dyslexia?

- Affects 3-12% 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 (DD is not monogenic), 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].

- In humans, polymorphisms in DD susceptibility genes are associated with structural temporo-parietal gray and white matter alterations [i.e. Darki et al., 2013]. ROBO2 has been associated with expressive vocabulary skills and atypical white matter development [Swanson et al., 2015].

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- 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

↓

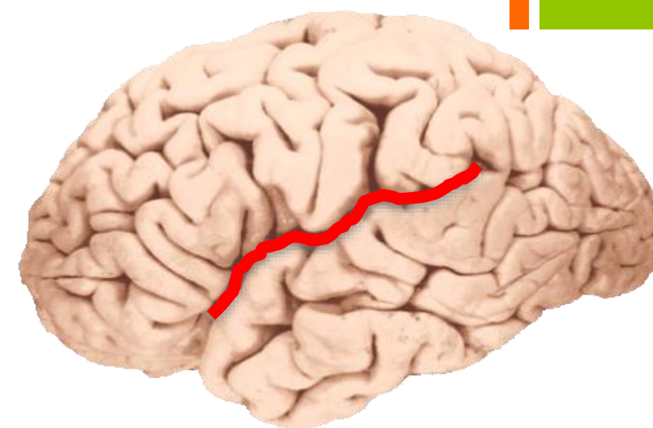
Subtle cortical malformation involving neuronal migration and other factors

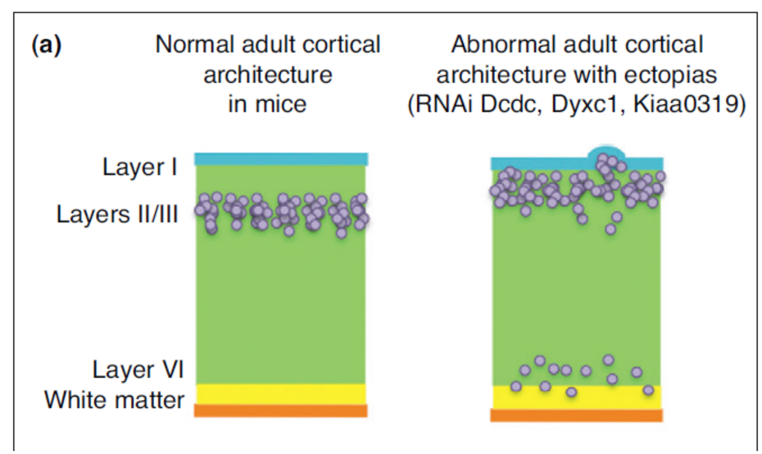
↓

Atypical cortico-cortical circuits

↓

Atypical sensorimotor, perceptual and cognitive processes critical for learning (to read)





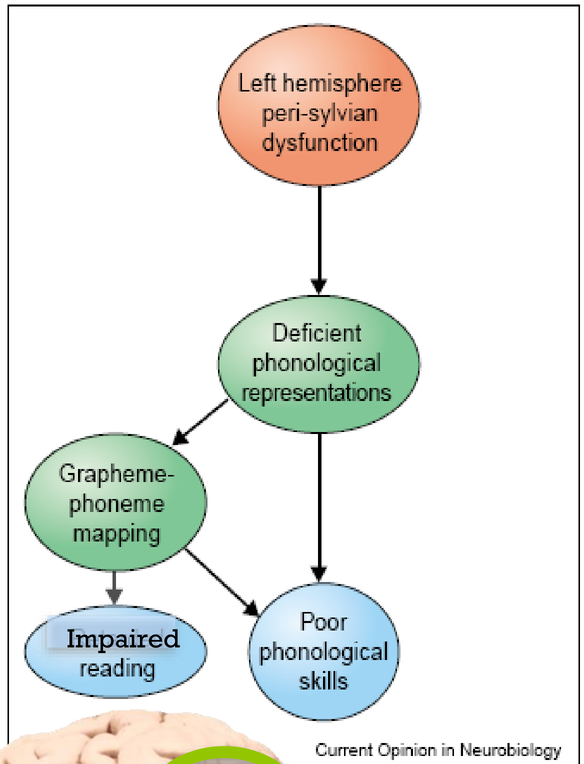
Giraud & Ramus, 2013

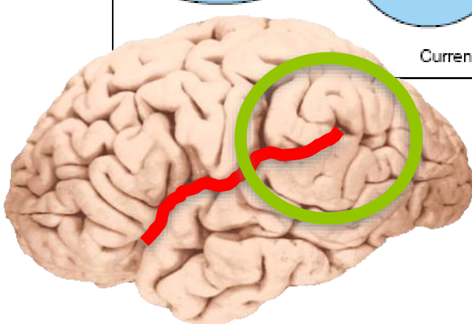
Selected Theories of Dyslexia

- Phonological-deficit hypothesis (e.g., Liberman et al., 1989)
- Double-deficit hypothesis (e.g., Fowler, 1991; Wolf & Bowers, 1999)
- The magnocellular theory (e.g., Livingstone et al., 1991; Stein, 2001)
- Rapid auditory processing theory (e.g., Tallal 1980, 2000)]
- The cerebellar theory (e.g., Nilson & Fawcett, 1990)]

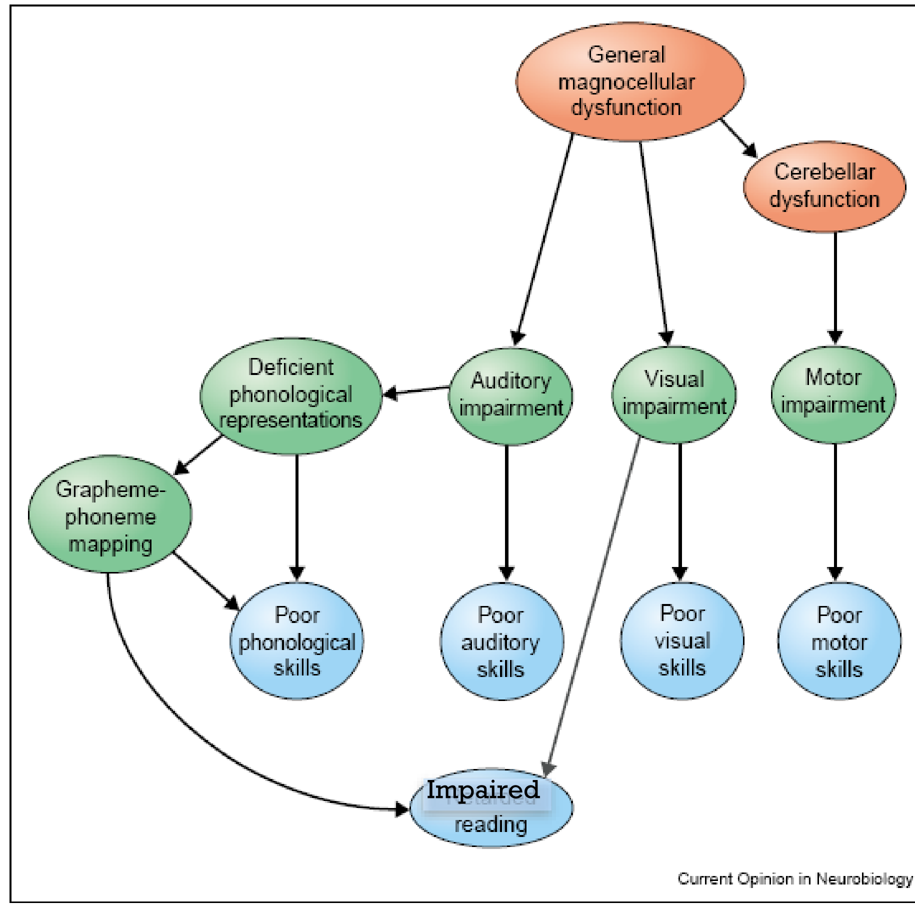
Theories

‘cognitive deficit’





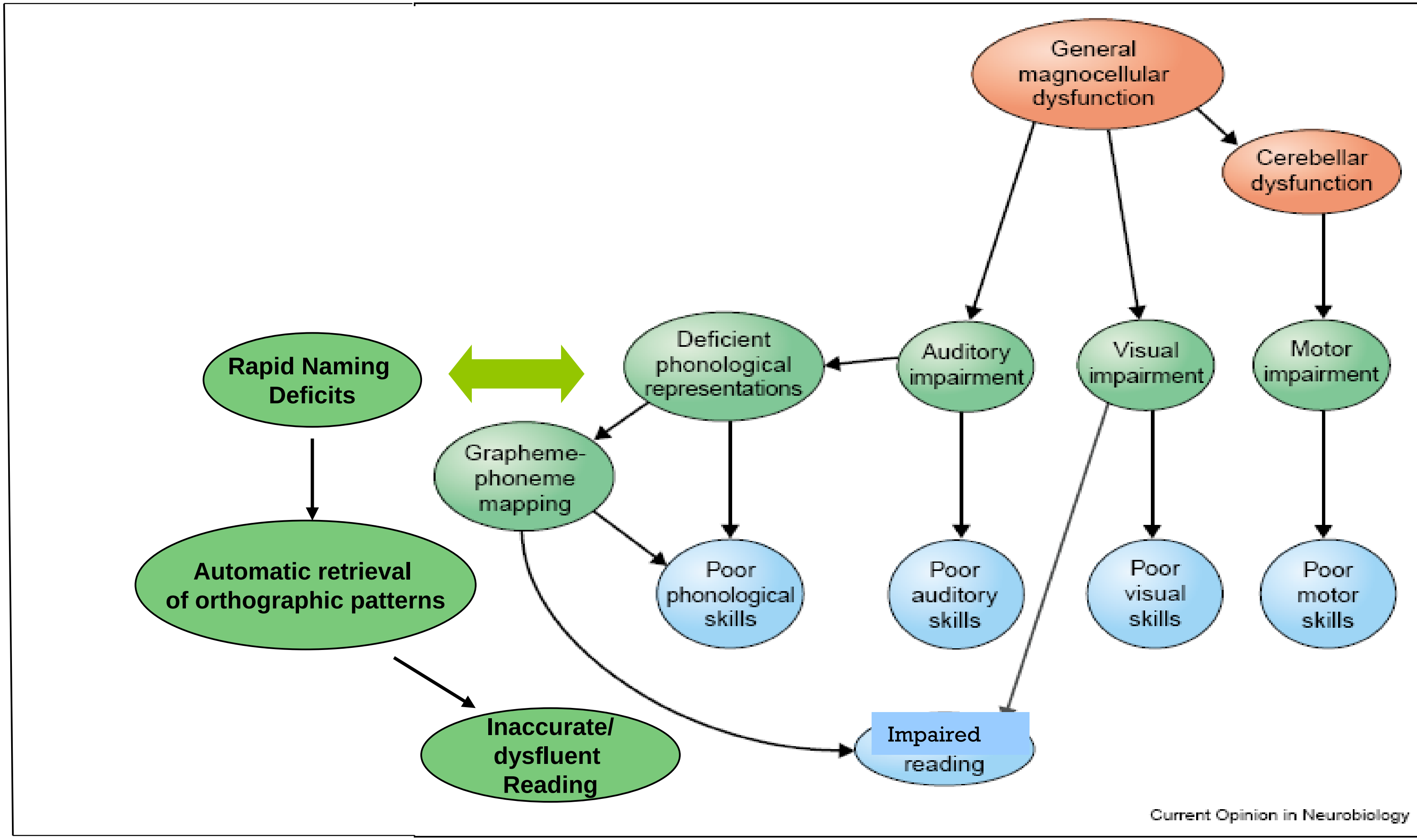
‘perceptual deficit’



[after Ramus, 2003]

Theories

‘double-deficit hypothesis’



[modified after Ramus, 2003]

Double-deficit hypothesis (e.g., Fowler, 1991; Wolf & Bowers, 1999)

- Deficits in phonological or naming-speed processes can impede reading acquisition

- Naming speed cannot be subsumed under phonology

- Phonological and naming-speed processes make unique contributions to reading

Rapid Automatized Naming (R.A.N.)

o	a	s	d	p	a	o	s	p	d
s	d	a	p	d	o	a	p	s	o
a	o	s	p	s	d	p	o	d	a
d	a	p	o	d	s	a	s	o	p
o	a	d	s	d	p	o	a	p	s

Cognitive requirements of RAN

- Attention to the letter stimulus
- Bihemispheric visual processes
- Integration of visual features with stored orthographic representations
- Integration of visual information with stored phonological information
- Access and retrieval of phonological label
- Activation and integration of semantic and conceptual information
- Motoric activation leading to articulation

(adapted from Wolf & Bowers, 1999)

Double-Deficit Subgroups

Average

- Intact Naming Speed
- Intact Phonology
- Intact Comprehension

Timing

- Impaired Naming Speed
- Intact Phonology
- Impaired Comprehension

Phonology

- Intact Naming Speed
- Impaired Phonology
- Impaired Comprehension

Double-Deficit

- Impaired Naming Speed
- Impaired Phonology
- Impaired Comprehension

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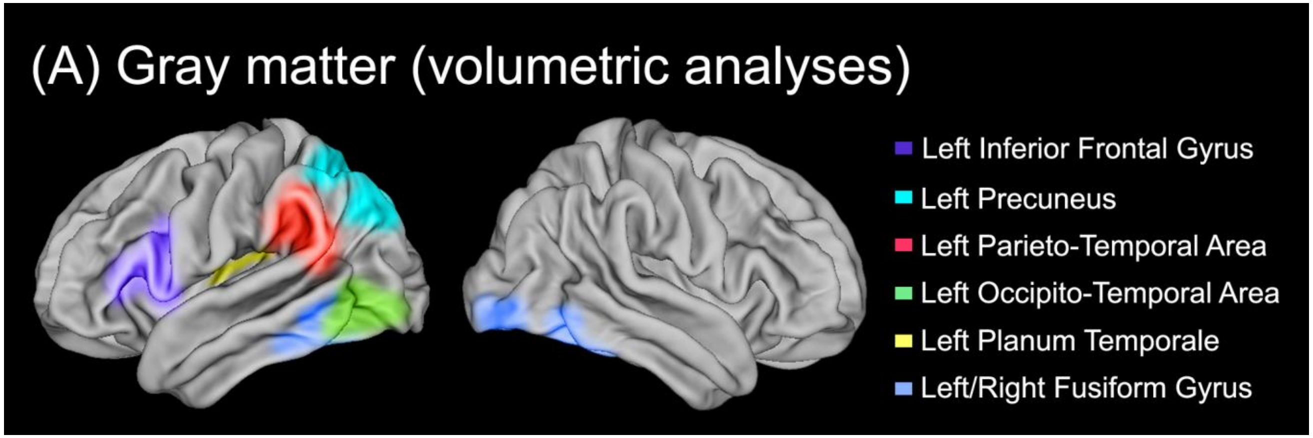
Structural and functional brain alterations in DD



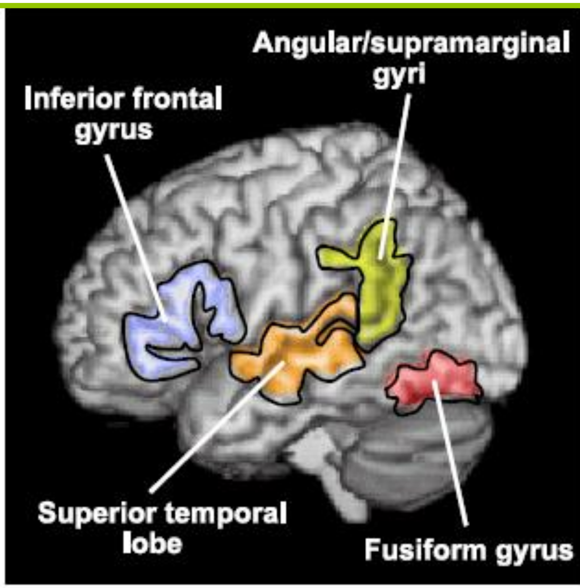
[e.g. see Meta-analyses: Richlan et al., 2013; Linkersdoerfer et al., 2012]

[e.g. see Meta-analyses: Richlan et al., 2011; Temple et al., 2002]

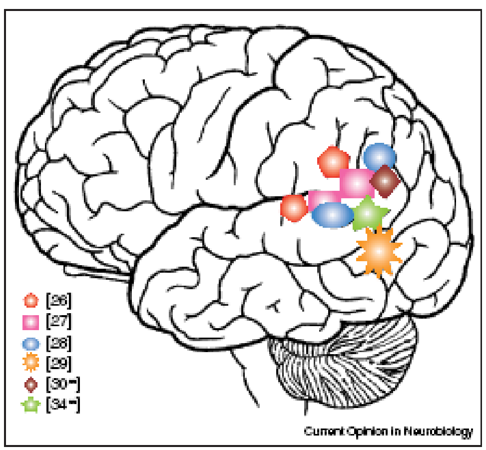
Example of input for a meta-analysis (Richlan et al., 2011)

Year	First author	Imaging	*N*	Dys	Con	Native language	Age mean (SD)	Task type	Contrast
Children									
2010 (poster)	Maurer	fMRI	66	31	35	German, Dutch	9.9 (range 7–12)	Animal/object decision	Words > symbols
2010	Blau	fMRI	34	18	16	Dutch	9.4 (0.4)	Letter–speech-sound integration	Interaction group × multisensory congruency
2009	Schulz	fMRI	30	15	15	German	11.5 (0.4)	Sentence evaluation	Sentence reading > fixation (age-matched)
2009	Van der Mark	fMRI	42	18	24	German	11.4 (0.6)	Phonological lexical decision	Pseudohomophones > fixation
2008	Meyler	fMRI	35	23	12	English	10.8 (0.5)	Sentence evaluation	Sentence reading > fixation (pre-remediation)
2007	Booth	fMRI	32	15	17	English	10.6 (2.2)	Semantic association judgment	Related word pairs > fixation
2006	Cao	fMRI	28	14	14	English	11.6 (range 8–14)	Word rhyme judgment	Conflicting trials > fixation
2006	Hoeft	fMRI	30	10	20	English	11.2 (0.5)	Word rhyme judgment	Rhyme > fixation (age-matched)
2001	Temple	fMRI	39	24	15	English	10.6 (1.4)	Visual letter matching and line matching	Matching letters > matching lines
Adults									
2010	Richlan	fMRI	33	15	18	German	18.0 (1.1)	Phonological lexical decision	Pseudowords > fixation
2010	Wimmer	fMRI	39	20	19	German	20.6 (6.8)	Phonological lexical decision	Pseudowords > fixation
2009	Blau	fMRI	26	13	13	Dutch	25.2 (4.6)	Letter–speech-sound integration	Multisensory congruency
2006	Brambati	fMRI	24	13	11	Italian	30.5 (range 13–63)	Silent reading	Reading (words and pseudowords) > false font string viewing
2005	McCrory	PET	18	8	10	English	20.2 (1.9)	Word reading and picture naming	Reading > false font string comparison
2002	Ingvar	PET	18	9	9	Swedish	23.5 (range 20–28)	Reading silently and aloud	Reading words silently > rest
2001	Paulesu	PET	72	36	36	English, Italian, French	24.3 (3.8)	Reading aloud	Reading (words and pseudowords) > rest
1997	Rumsey	PET	31	17	14	English	26.0 (6.5)	Reading aloud	Pseudowords > fixation
1996	Paulesu	PET	10	5	5	English	26.2 (1.9)	Letter pair rhyme judgment	Letter pair rhyming > shape similarity judgment

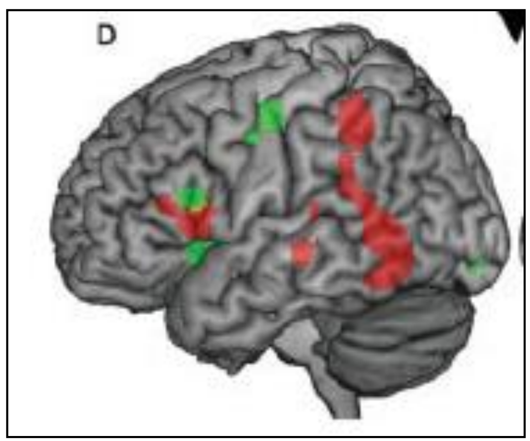
Typical reading network with its key components:



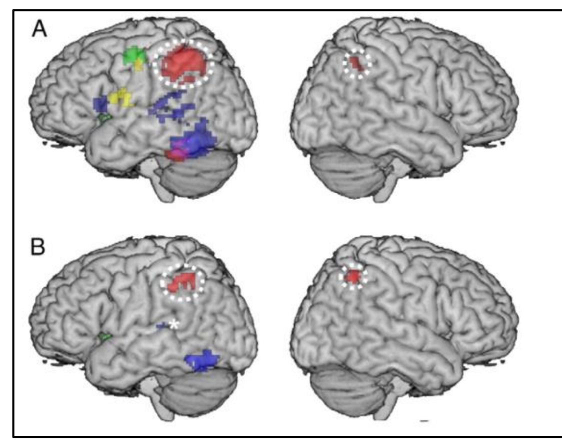
Temporo-parietal/Temporo-occipital dysfunction in dyslexia:



[Temple, 2002]



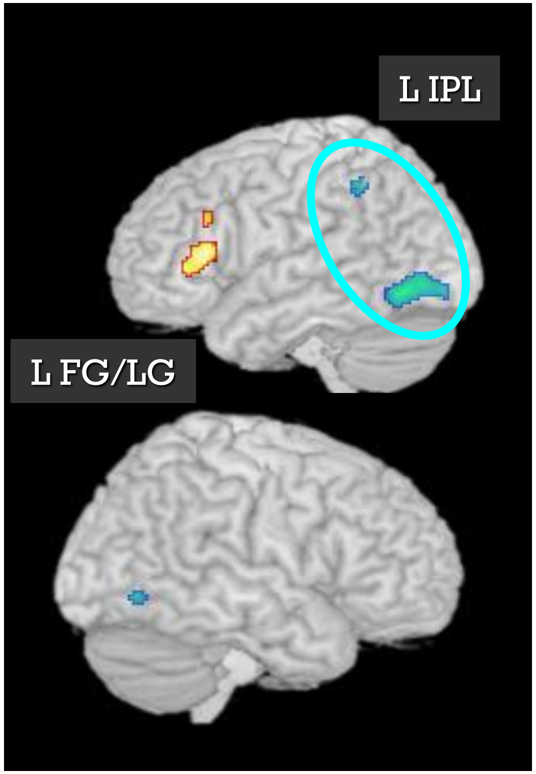
[Meta-analysis: 17 studies; Richlan *et al*., 2009]



[Meta-analysis: 18 studies; Richlan *et al*., 2011]

Children with dyslexia show REDUCED activation of the posterior brain system compared to good readers

AND younger children (2-4 years) that read similarly

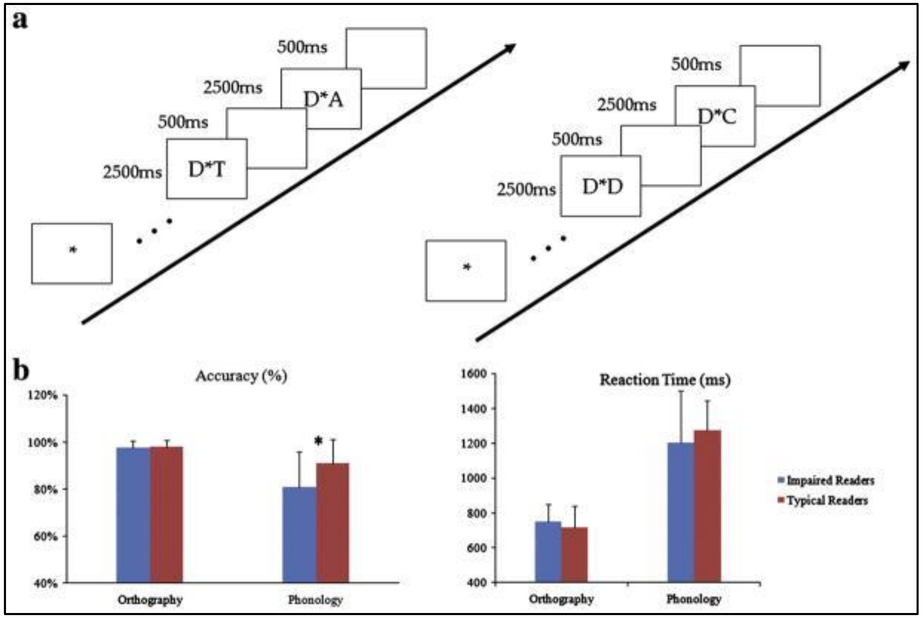


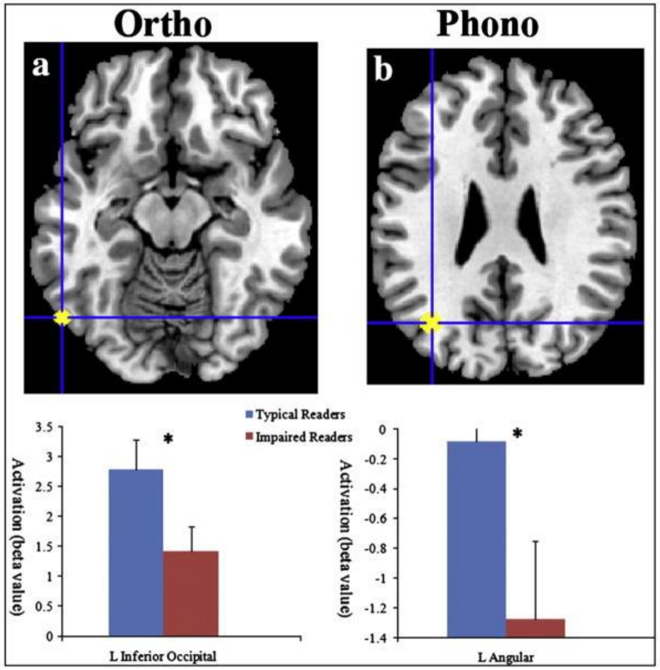
Dyslexia: <u>Different</u> in posterior networks

[Hoeft et al., 2007]

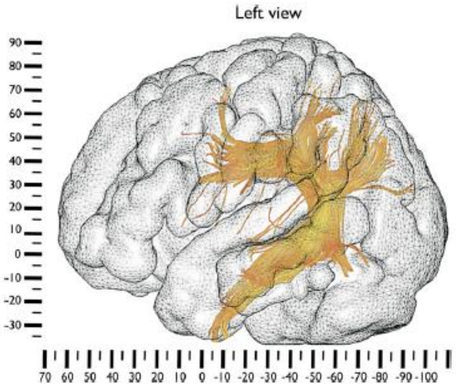
Neural deficits in second language reading: fMRI evidence from Chinese children with English reading impairment

Hanlin You [a], Nadine Gaab [b], Na Wei [c], Alice Cheng-Lai [d,e], Zhengke Wang [a], Jie Jian [a], Meixia Song [c], Xiangzhi Meng [a,e,*], Guosheng Ding [c,*]





Structural brain differences (white matter): Typical and atypical readers

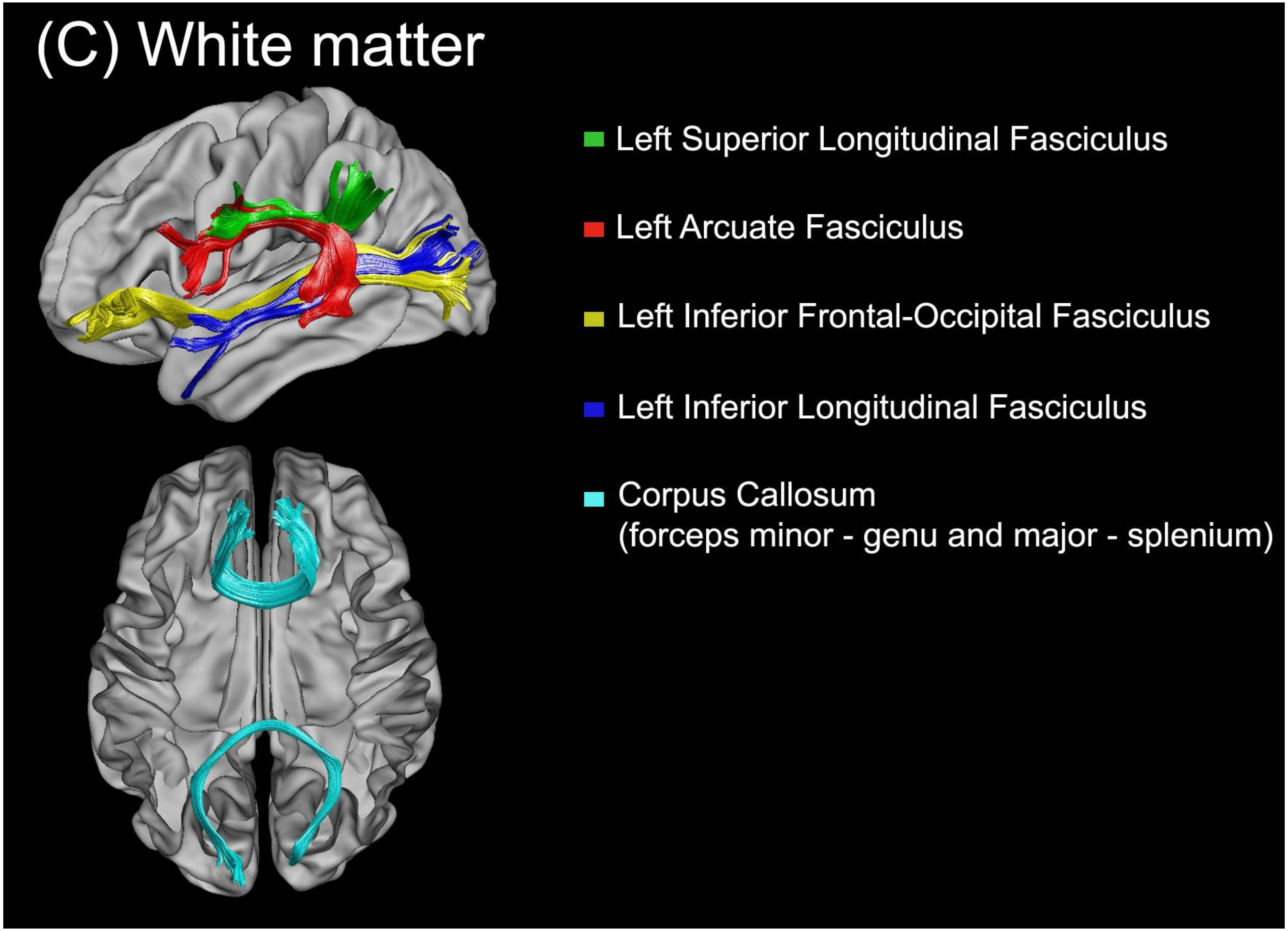


[Catani, 2008]

- 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, Yeatman & Wandell, 2011].

- Differences may reflect weakened white-matter connectivity (e.g., less myelination, reduced tract volume) among left-hemispheric areas that support reading.

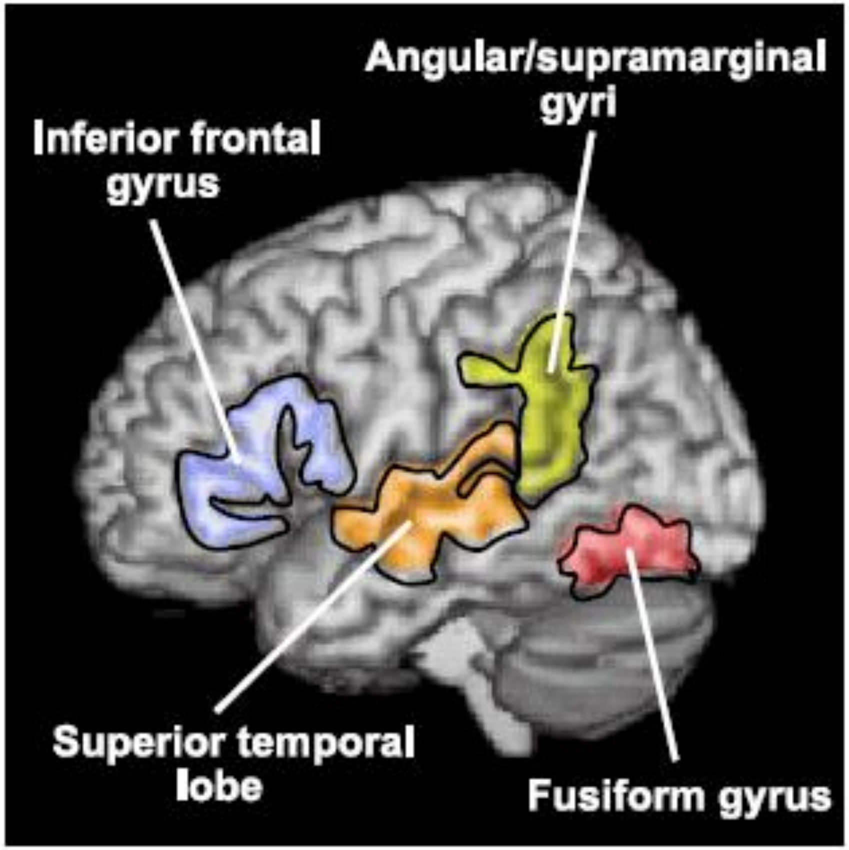
White matter alterations in DD



Joseph-Jules Dejerine's Discovery (1887)

- "Verbal blindness" in Mr. C
- Patient unable to recognize individual letters or a written word
- Spoken language intact
- Writing preserved
- Visual recognition of objects, faces, drawings, and even digits often intact
- Tactile or motor knowledge of letter intact

Where was Mr. C's Lesion?



Patient with Pure Alexia (without agraphia)

- http://www.youtube.com/watch?v=b_sHZRoXs6A

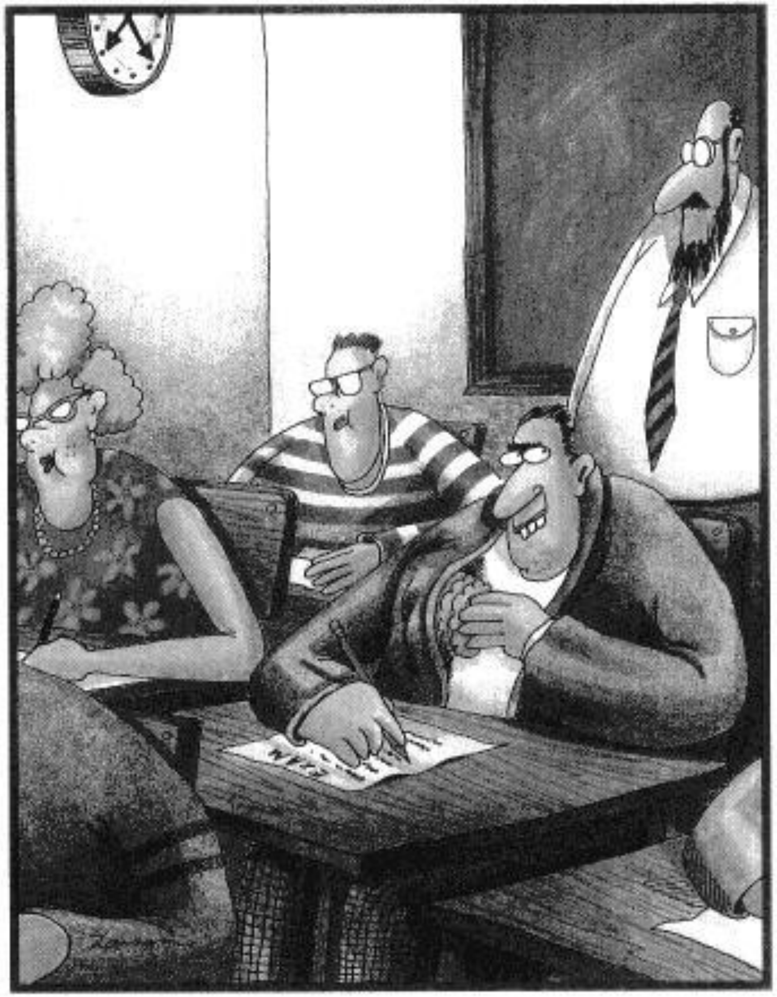
Patient with Alexia describing his symptoms, brain scan

- https://www.youtube.com/watch?v=GJZnpd4NQ98

Overview

- Atypical language development
- Neurobiology of atypical language development
- Atypical reading development/Developmental Dyslexia
- Theories of Developmental Dyslexia
- Neurobiology of atypical reading development
- Remediating the atypical reading brain
- Early identification of children at risk for reading impairments
- Challenges and implications for educational practice and policy

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)

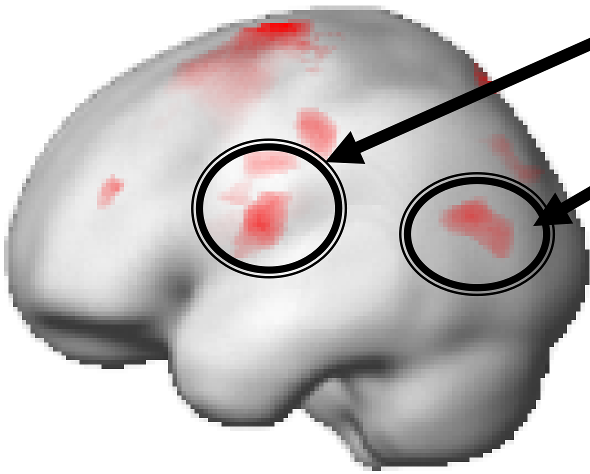
	Dyslexic-reading children				Normal-reading children			
	Pretraining	Posttraining	T-stat	*P*	1st scan	2nd scan	T-stat	*P*
Reading: WJ-RMT								
Word ID	78.2 (56–95)	86.0 (72–99)	3.9	0.0005	109.0 (95–120)	108.3 (97–126)	0.6	0.6
Word Attack	85.5 (72–102)	93.7 (82–109)	6.8	0.0001	112.3 (99–132)	109.4 (99–125)	1.1	0.3
Passage Comp	83.3 (51–103)	88.9 (77–107)	2.9	0.005	112.8 (104–120)	110.3 (100–122)	1.8	0.03
Language: CELF-3								
Receptive	92.5 (69–120)	101.3 (75–122)	3.6	0.001	118.6 (108–135)	121.8 (108–139)	1.5	0.2
Expressive	95.0 (61–125)	102.2 (80–150)	2.8	0.006	112.3 (102–125)	113.8 (92–139)	0.5	0.6
Rapid Naming	79.1 (35–97)	86.5 (67–103)	2.8	0.006	106.8 (94–121)	104.3 (82–124)	0.9	0.4

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
8 weeks intervention

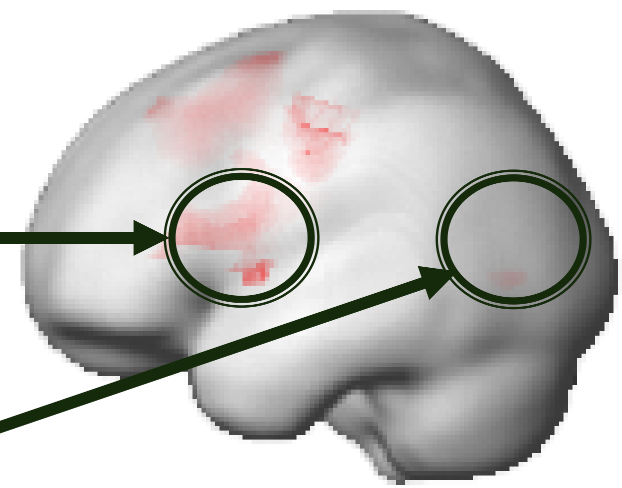
Control



Frontal AND Temporo-parietal

Dyslexia

Frontal but NOT Temporo-parietal



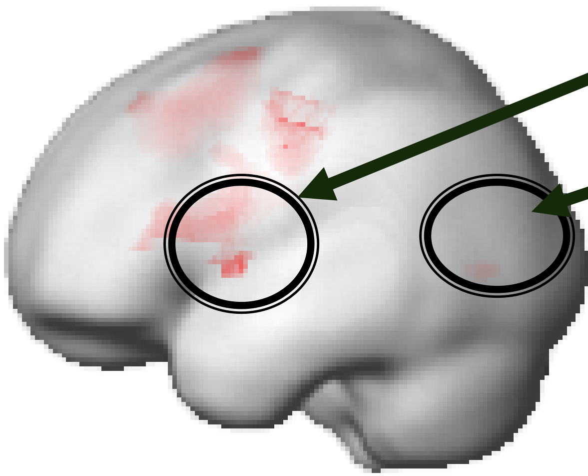
Example:

B D = Rhyme
B K = Do Not Rhyme

[Temple et al. (2003) PNAS, 100]

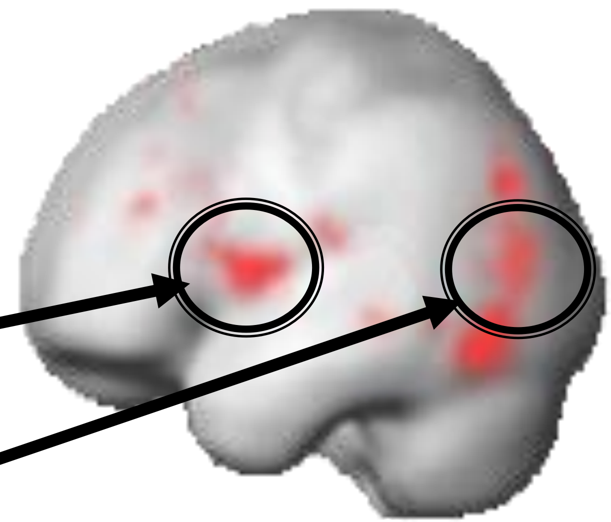
Neural effect of intervention

Pre-Intervention



Frontal but NOT Temporo-parietal

Post-Intervention



Increased activity in Frontal AND Temporo-parietal

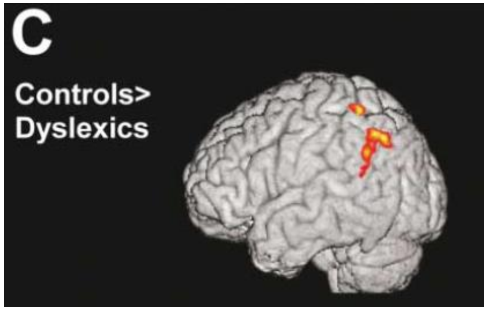
After training, metabolic brain activity in dyslexics more closely resembles that of typical readers.

[Temple et al. (2003) PNAS, 100]

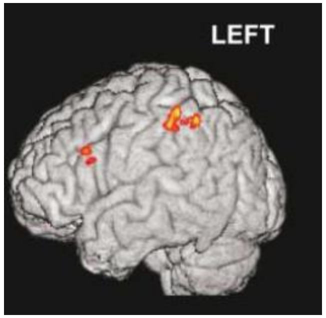
Neural Changes following Remediation in Adult Developmental Dyslexia

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 Flowers[1,2]

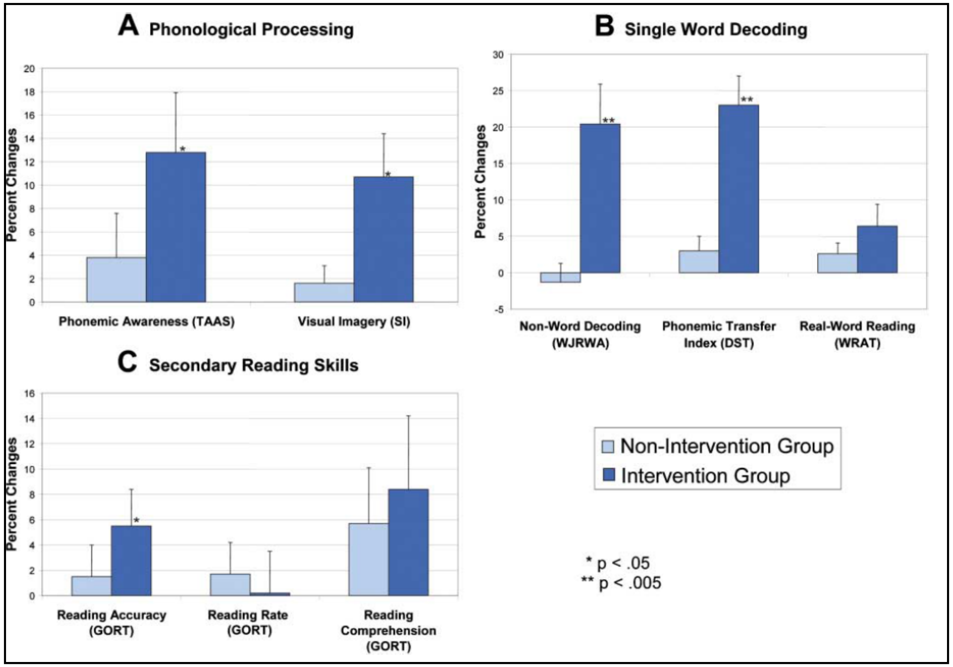
n= 38
Intervention: Lindamood-Bell (8 weeks)



Sound deletion > word repetition



Post remediation > Pre-remediation



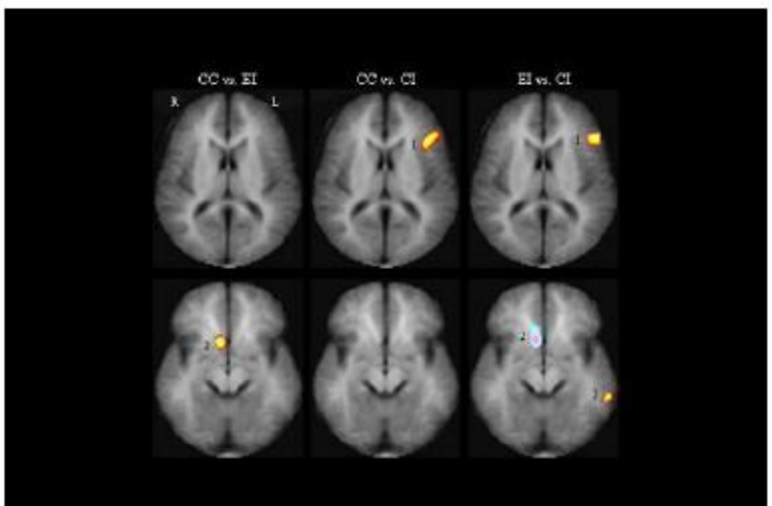
Development of Left Occipitotemporal Systems for Skilled Reading in Children After a Phonologically-Based Intervention

Bennett A. Shaywitz, Sally E. Shaywitz, Benita A. Blachman, Kenneth R. Pugh, Robert K. Fulbright, Pawel Skudlarski, W. Einar Mencl, R. Todd Constable, John M. Holahan, Karen E. Marchione, Jack M. Fletcher, G. Reid Lyon, and John C. Gore

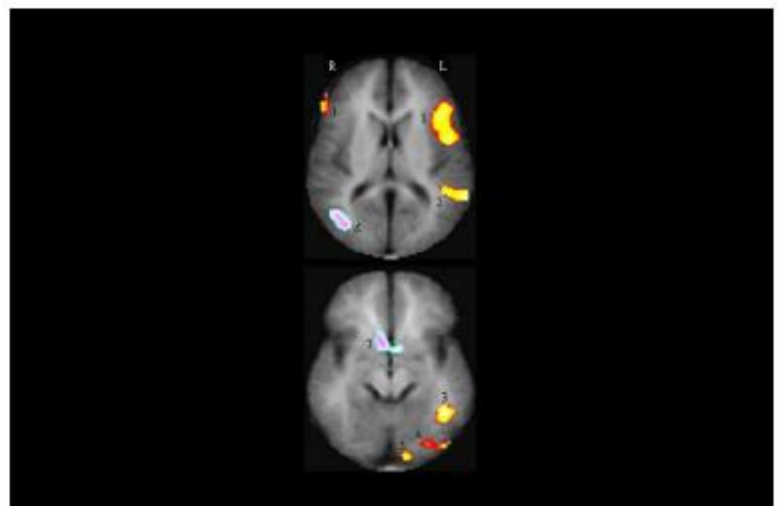
N =77 (6-9yo)
EI = experimental intervention
CI = community intervention
CC = community control

Hear "B" → match letter

Intervention:
a) sound-symbol associations
b) Phoneme analysis/blending
c) Fluency
d) Oral reading of stories
e) dictation



Post> pre ; between group comparison



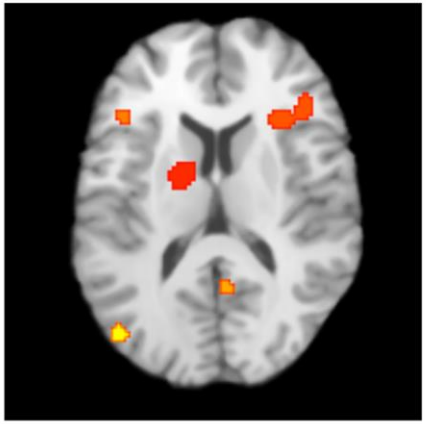
Blue = year 1> year 3
Red/Yellow = Year 3 > Year 1

Neuroimaging of Reading Intervention: A Systematic Review and Activation Likelihood Estimate Meta-Analysis

Laura A. Barquero[1]*, Nicole Davis[1,2,3,4], Laurie E. Cutting[1,2,3,4,5]

Table 1. Participant groups and interventions.

Study	RD N	CT N	Age	Intervention	Dosage
Simos et al., 2002	8; 6 received Phono-Graphix, 2 received Lindamood Phonemic Sequencing	8	7–17 yrs	Phono-Graphix (Read America, Orlando FL) Lindamood Phonemic Sequencing (Lindamood-Bell, San Luis Obispo, CA)	80 hrs: 1-2 hr/day over 8 wk
Aylward et al., 2003	10	11	139.1 (9.8) months, 137.5 (7.9) months	Instruction in linguistic awareness, alphabetic principle, fluency, and reading comprehension	28 hrs: 2hr/day over 14 session days (3 wk)
Temple et al., 2003	20	12	8–12 yrs	Fast ForWord Language (Scientific Learning Corporation, Oakland, CA)	100 min/day, 5 days/wk, average 27.9 days
Eden et al., 2004	19 total; 9 received intervention	19	adults, RD 44.0 (9.4), CT 41.1 (9.7)	Multisensory instruction including sound awareness, letter-sound association, articulatory feedback administered by Lindamood-Bell Learning Corporation staff	3 hr/day, 8 wks, avg 112.5 hr total
Shaywitz et al., 2004	49 total; 37 received experimental intervention, 12 received community intervention	28	6.1 – 9.4 yrs; RD experimental 7.9 (0.5), RD community 8.1 (0.6), CT 8.0 (0.5)	Experimental intervention [127] included sound-symbol associations, blending, timed reading for fluency, oral reading, dictation	50 min/day for 8 months
Simos, et al., 2005	16; 13 responders, 3 non-responders	17	5.6–7.2 yrs at baseline (Low risk group 5.6–6.5, High risk group 6.0–7.2) 6.4–8.1 yrs at posttest (Low risk 6.4 – 7.5, High risk group 7.0 – 8.1)	Proactive Reading and Responsive Reading [128]	40 min/day, 5 day/wk for 8 months
Richards et al., 2006	18; 8 orthographic treatment, 10 morphological treatment	21	RD 130.8 months, CT 132.6 months	Instruction in alphabetic principle, composition, and either orthographic spelling treatment or morphological spelling treatment	28 hr total: 2 hr/day for 14 sessions over 3 wk
Hoeft et al., 2007	64 struggling readers (identified by teachers, many had scores in average range)	-	10.0 (1.09) yrs	Power4Kids Reading Initiative. Many participants received 1 of 4 interventions, but there was no significant effect of intervention on decoding scores.	about 6 months during school year
Richards et al., 2007	20; 11 phonological treatment, 9 nonphonological treatment	10 nonphonological treatment	RD phonological 137.7 (10.00) months, RD nonphonological 134.60 (11.10) months, CT 128.60 (8.00) months	Phonological treatment included explicit written language instruction using phonological working memory, phoneme-grapheme correspondences in spelling, and science report writing [129]. Nonphonological treatment included nonverbal virtual reality supported science problem solving [130]	24 hrs total—8 sessions over 2 wks with 3 hr/session
Simos, Fletcher, Sarkari, Billingsley-Marshall, et al., 2007	15	-	7–9 years	Phono-Graphix [131] and Read Naturally [132]	16 weeks total: 2 hr/day for 8 wks Phono-Graphix, 1 hr/day for 8 wks Read Naturally
Simos, Fletcher, Sarkari, Billingsley, et al., 2007	15; 8 responders, 7 nonresponders (same as Simos, et al., 2007 above)	10	7–9 years	Phono-Graphix [131] and Read Naturally [132]	16 weeks total: 2 hr/day for 8 wks Phono-Graphix, 1 hr/day for 8 wks Read Naturally
Meyler et al., 2008	23 (possible overlap with Hoeft, et al., 2007)	12	5th grade	Power4Kids project used four programs: Corrective Reading, Wilson Reading, Spell Read Phonological Auditory Training (PAT), Failure Free Reading	100 hrs total over 6 months
Odegard et al., 2008	12 total: 6 responders, 6 nonresponders	6	10 – 14 yrs	Take flight: A comprehensive intervention for students with dyslexia [133]	90 min/day, 4 days/wk for 2 school years
Richards & Berninger, 2008	18 (same as Richards et al., 2006)	21	RD 130.8 months, CT 132.6 months	Instruction in alphabetic principle, composition, and either orthographic spelling treatment or morphological spelling treatment	28 hrs total—14 sessions over 3 wks with 2hr/session;
Davis et al., 2011	10 total: 5 responders, 5 nonresponders	4	7.5 (0.43) yrs	Intervention consisted of sight word reading, letter sound practice, decoding practice, and reading for fluency.	45 min, 3 days/wk, 17 weeks
Farris et al., 2011	10 total: 5 responders, 5 nonresponders (same as Odegard et al., 2008)	5	10 – 14 yrs	Take flight: A comprehensive intervention for students with dyslexia [133]	90 min/day, 4 days/wk for 2 years
Hoeft et al., 2011	25	20	RD 14.0 (1.96) CT 11.0 (2.57)	*This study did not provide an intervention.* 11 participants received some form of intervention, but no differences were observed for intervention.	-
Rezaie et al., 2011a	20 total: 10 Adequate Responders (AR), 10 Inadequate Responders (IR)	20	Adequate Responders 158±7 months, Inadequate Responders 153±11 months, CT 151±11 months	Instruction included word study, fluency, vocabulary, comprehension [134]	45–50 min/day over 1 schoolyear
Rezaie et al., 2011b	27 total: 16 AR, 11 IR (possible overlap with Rezaie, et al., 2011a)	23	Adequate Responders 159±9 months, Inadequate Responders 156±16 months, CT 153±12 months	Instruction included word study, fluency, vocabulary, comprehension [134]	45–50 min/day over 1 schoolyear
Yamada et al., 2011	7 (at-risk)	7 (on-track)	At-risk 5.6 (0.2) yrs, On-track 5.7 (0.3) yrs	Early Reading Intervention [135]	30 min/day, 3 months
Gebauer Fink, Kargl et al., 2012	20 total (poor reading and spelling): 10 Treatment (TG), 10 Waiting Group (WG)	10	10–15 yrs, (M = 11.80; SD = 1.58)	Morpheus: a computer-aided morpheme-based spelling training in German [136]	Daily handwritten and computer homework, 1/wk instructor-guided courses for 2 hr, over 5 wks.
Bach et al., in press	6 poor readers (group classification made at follow-up)	11	Poor Readers 6.33±0.19 yr, Normal Readers 6.35±0.29 yr	Graphogame: a computerized training game teaching grapheme-phoneme correspondences in German [137–139]	321.5±124.3 min over 8 wk



Why do some kids improve and others don’t?

- Some children do compensate and some don’t
- What is the brain basis of compensation?

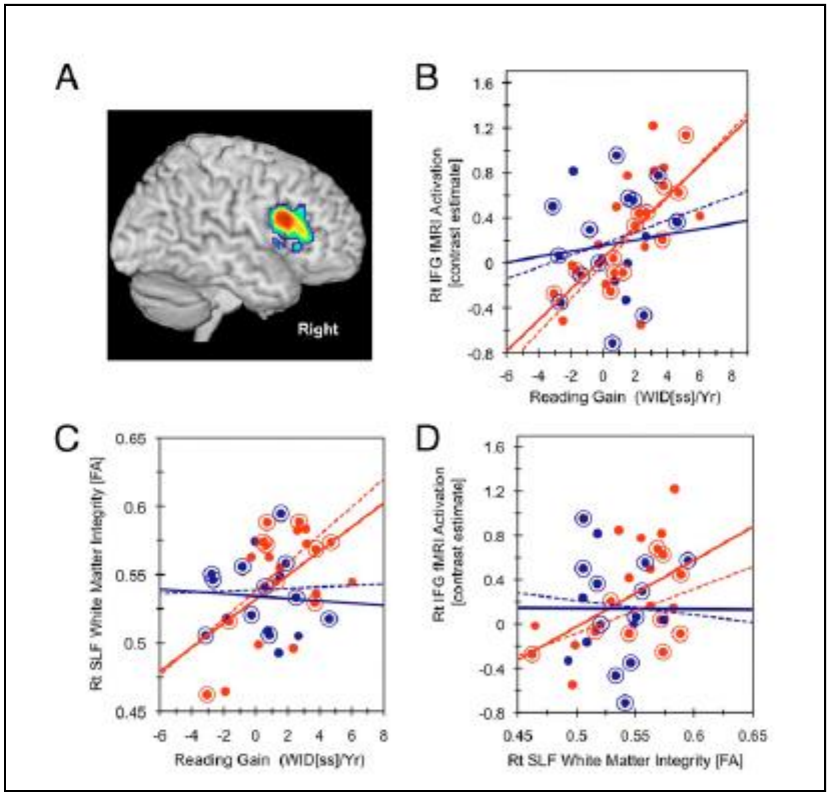
→ more like typical development?

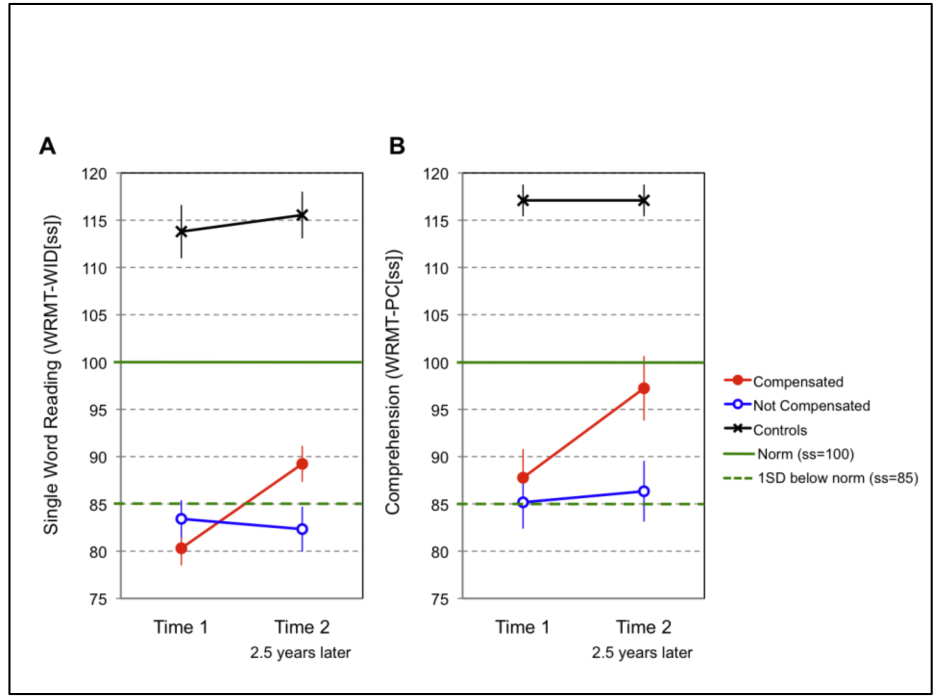
→ Alternative pathway?

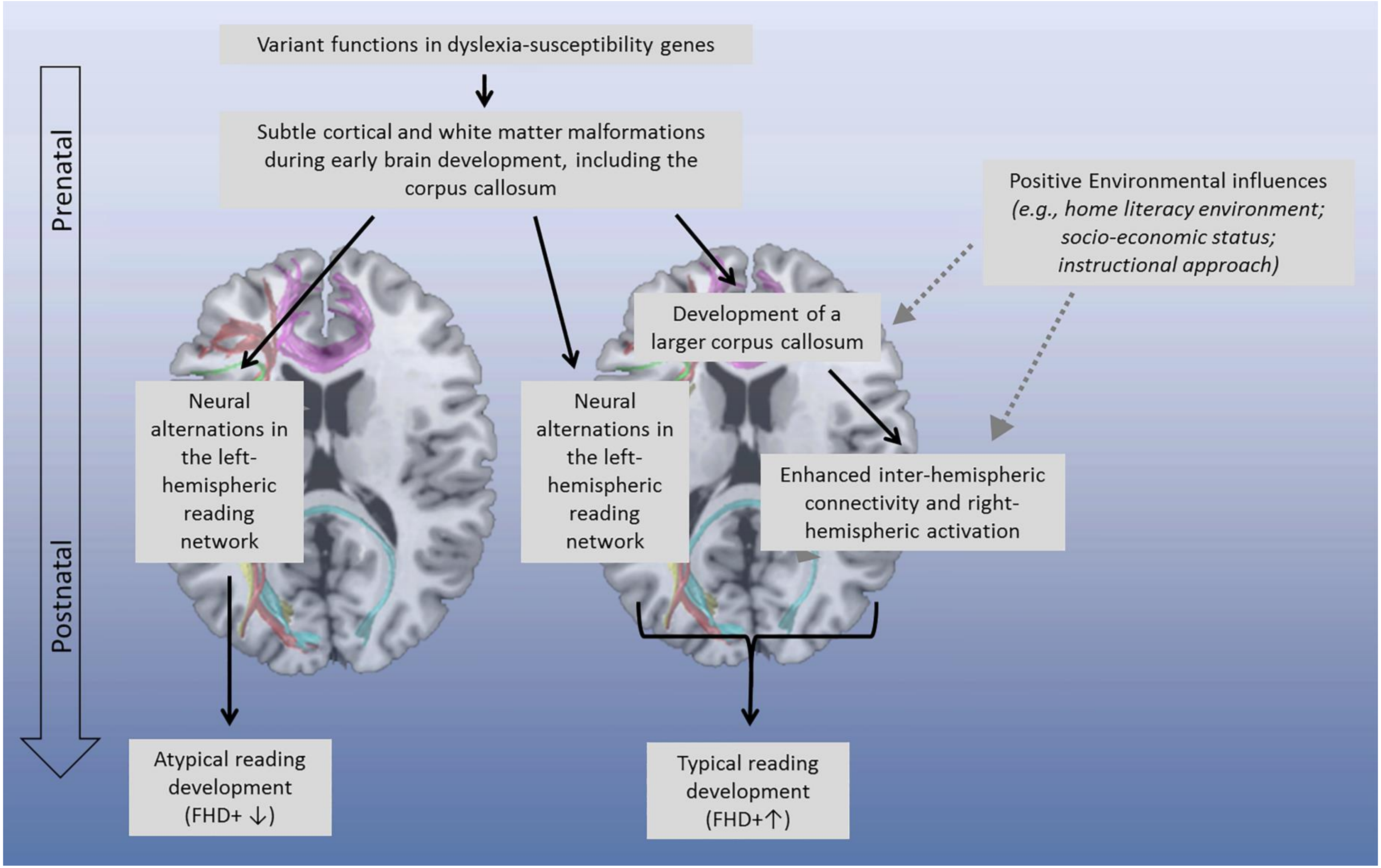
Who does compensate?

Neural systems predicting long-term outcome in dyslexia

Fumiko Hoeft[a,b,1], Bruce D. McCandliss[c], Jessica M. Black[a,d], Alexander Gantman[a], Nahal Zakerani[a], Charles Hulme[e], Heikki Lyytinen[f], Susan Whitfield-Gabrieli[g], Gary H. Glover[h], Allan L. Reiss[a,b,h], and John D. E. Gabrieli[h]





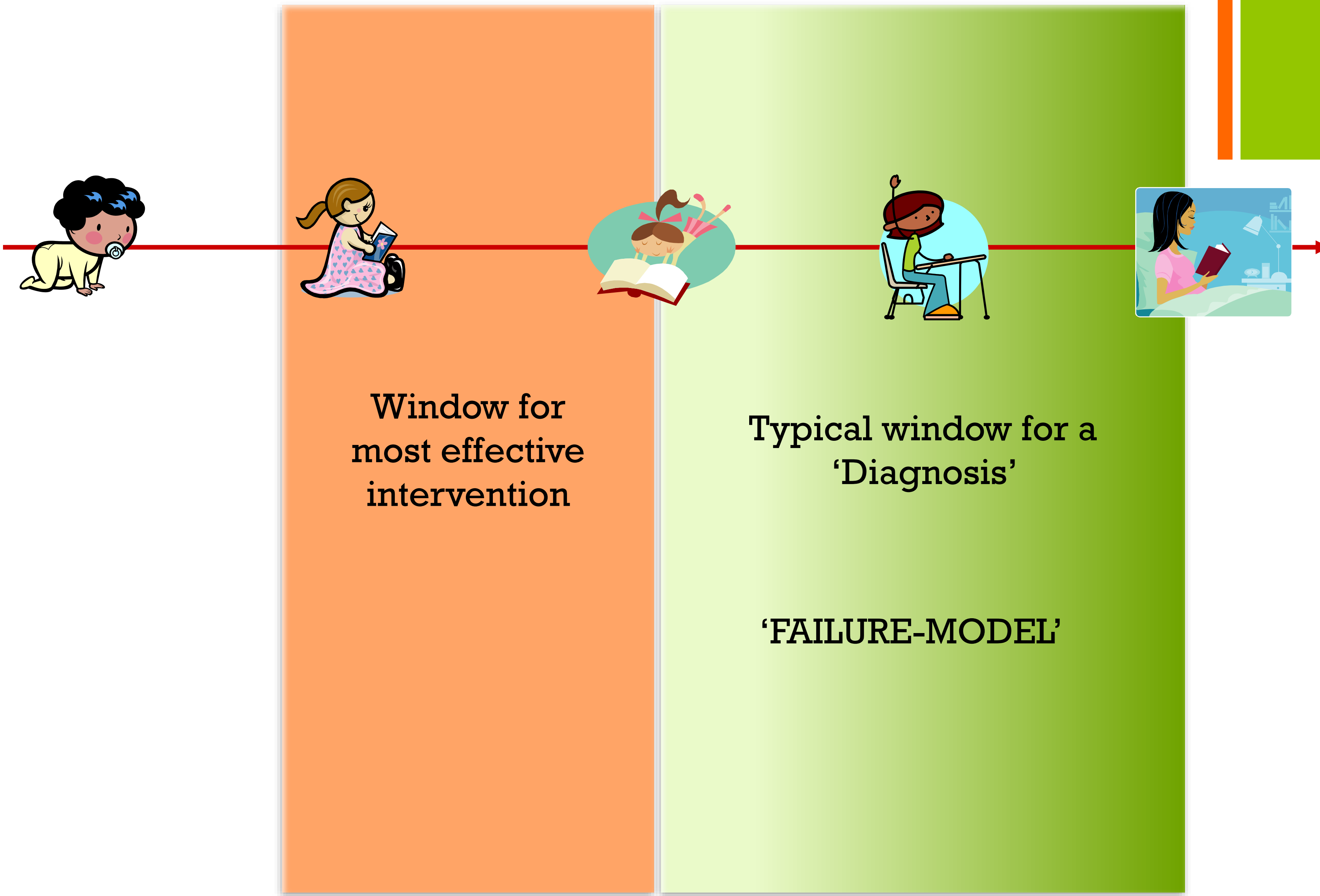


Xi et al., under review

Overview

- Atypical language development
- Neurobiology of atypical language development
- Atypical reading development/Developmental Dyslexia
- Theories of Developmental Dyslexia
- Neurobiology of atypical reading development
- Remediating the atypical reading brain
- Early identification of children at risk for reading impairments
- Challenges and implications for educational practice and policy

The dyslexia paradox



Early versus late intervention

- A meta-analysis comparing intervention studies offering at least 100 sessions, reported larger effect sizes in kindergarten/1st grade than in 2nd and 3rd grades (Wanzek & Vaughn, 2007; Wanzek et al., 2013) .
- 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).
- Overall, converging research points to the importance of early and individualized interventions for at-risk students for improving the effectiveness of remediation (Catts, et al., 2015; Denton & Vaughn, 2008; Connor et al., 2009; Shaywitz, Morris, & Shaywitz, 2008, Torgesen, et al., 1999; Flynn, Zheng, & Swanson, 2012; Vellutino et al., 1996; Morris, Lovett, Wolf et al., 2012; Morris et al., 1997).

Early behavioral predictors of dyslexia

Key childhood predictors of reading problems (e.g. Scarborough, 1998):

- phonological awareness
- rapid automatized naming
- Expressive/receptive vocabulary
- pseudoword repetition
- Letter (sound) naming
- [Oral comprehension/vocabulary]
- Puolakanaho et al., 2007 showed that familial risk, letter knowledge, phonological awareness and rapid automatized naming at 3.5 years predicted later DD. Additionally, those children who later developed DD, exhibited auditory and speech processing deficits at a very early age.

The Boston Longitudinal Dyslexia Study (BOLD)

Early Identification
children at-risk

Diagnosis
Dyslexia

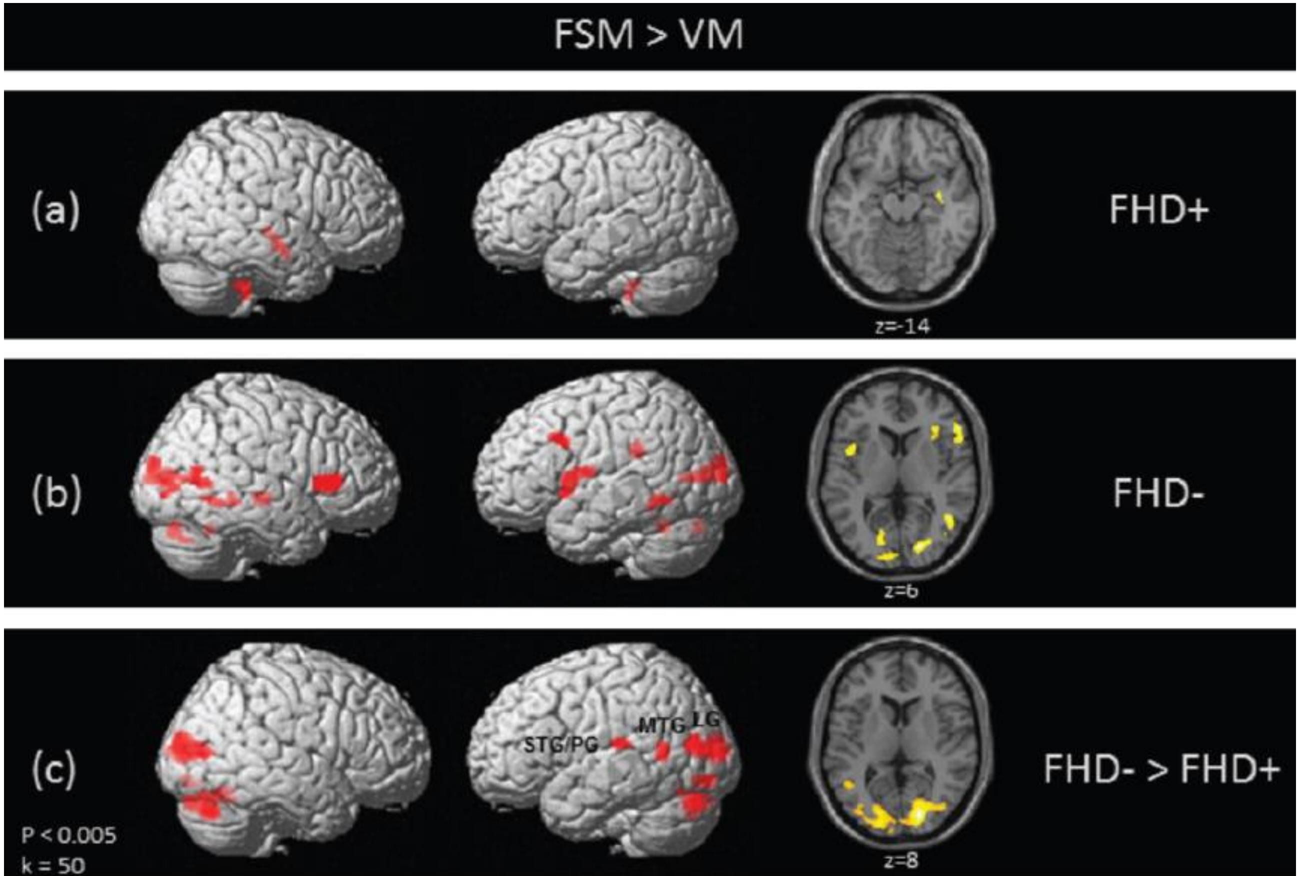
- Functional MRI
- Structural MRI
-Behavioral tests
-Psychophysics
-Questionaires
-DNA

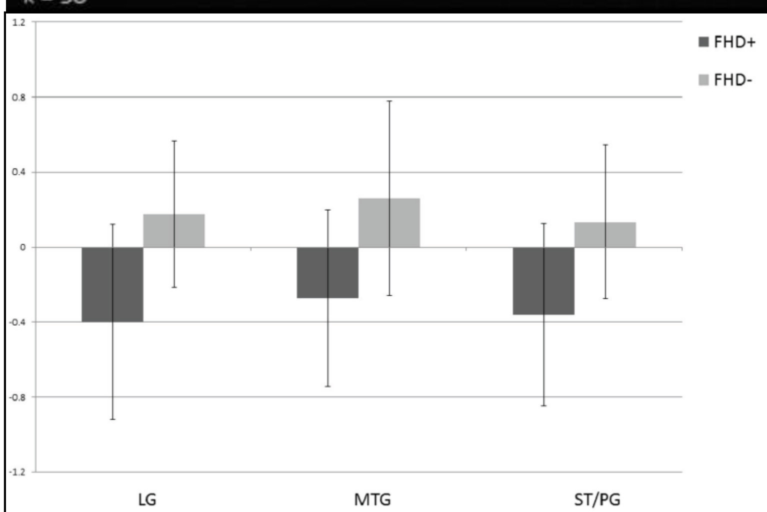
Follow up:
-prior to first grade
-prior to second grade
-prior to third grade

- To date 114 children enrolled longitudinally (64 FHD+/50 FHD-).
- Pre-readers (Word ID <5), reading instruction within next year.

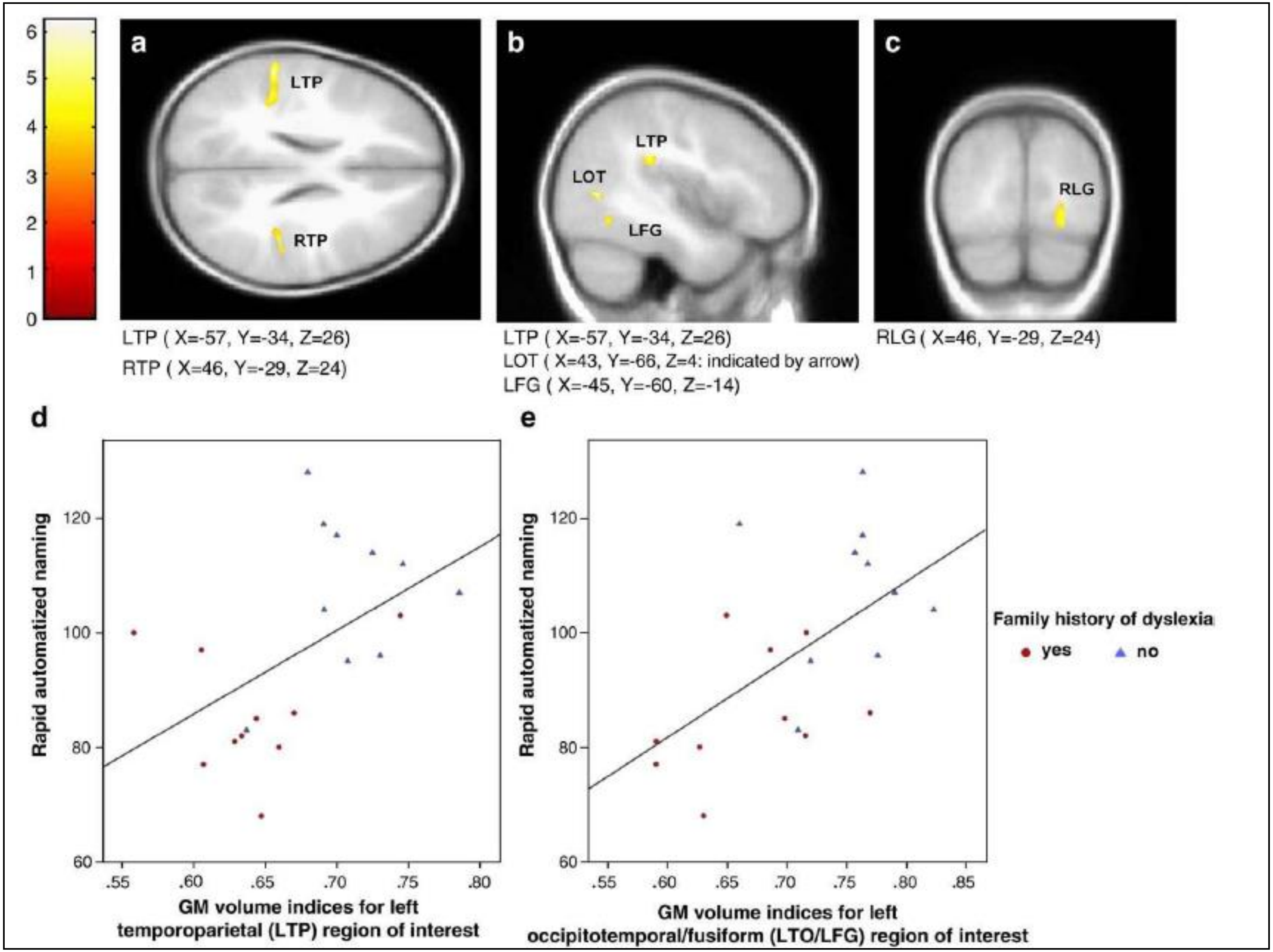
YEAR 1 (prereading status)	YEAR 2 (beginning readers)	YEAR 3/4 (readers)
Significant differences in:	*Significant differences in:*	*Significant differences in:*
Expressive and receptive language/content	Expressive language/ Language content	Core and receptive Language
Phonological processing	Phonological processing	
Rapid automatized naming	Rapid automatized naming	Rapid automatized naming
Rapid auditory Processing	Letter knowledge	
	Single word reading (timed/untimed)	Single word reading (timed/untimed)
	Passage comprehension	Passage comprehension
	Spelling	Spelling
		Reading Fluency
all $p<0.05$	*all $p<0.05$*	*all $p<0.05$*

No differences in
IQ, age, Home Literacy, SES





[Raschle *et al.*, PNAS 2012]



[Raschle *et al*., 2010]

ORIGINAL ARTICLE

Atypical Sulcal Pattern in Children with Developmental Dyslexia and At-Risk Kindergarteners

Kiho Im[1,4], Nora Maria Raschle[2,4,6], Sara Ashley Smith[2], P. Ellen Grant[1,3,4], and Nadine Gaab[2,4,5]

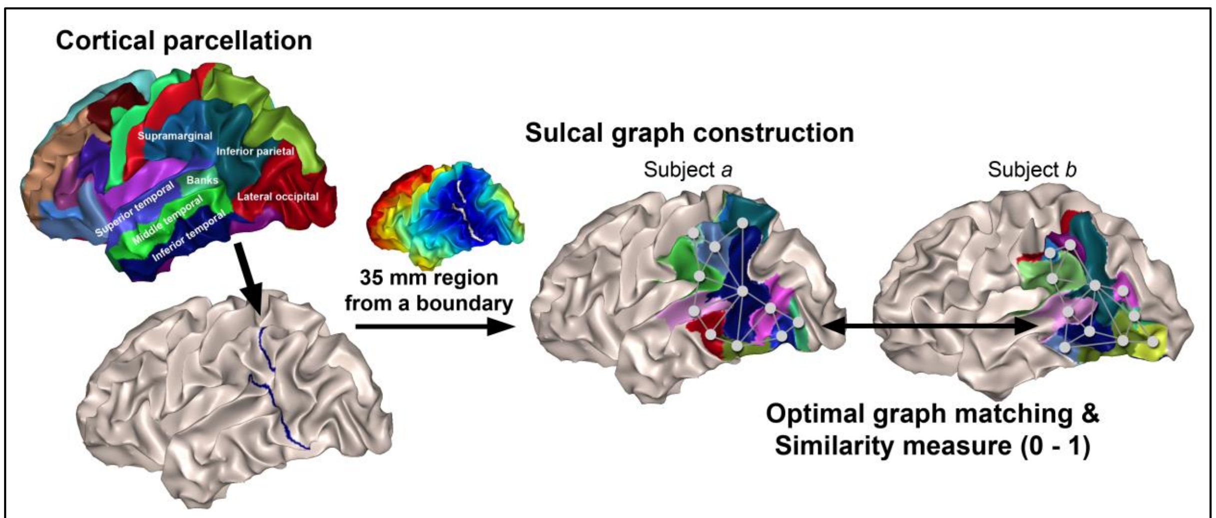
<u>Four groups:</u>

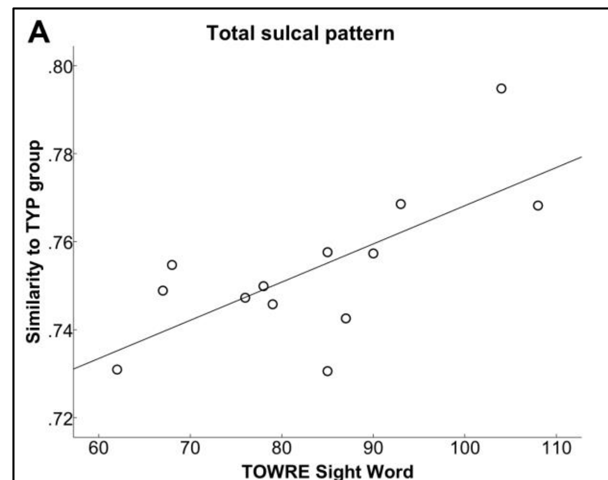
n = 16 Beginning readers FHD-
n = 15 Beginning readers FHD+

n = 15 Developmental Dyslexia
n = 13 Typical developing

- 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.

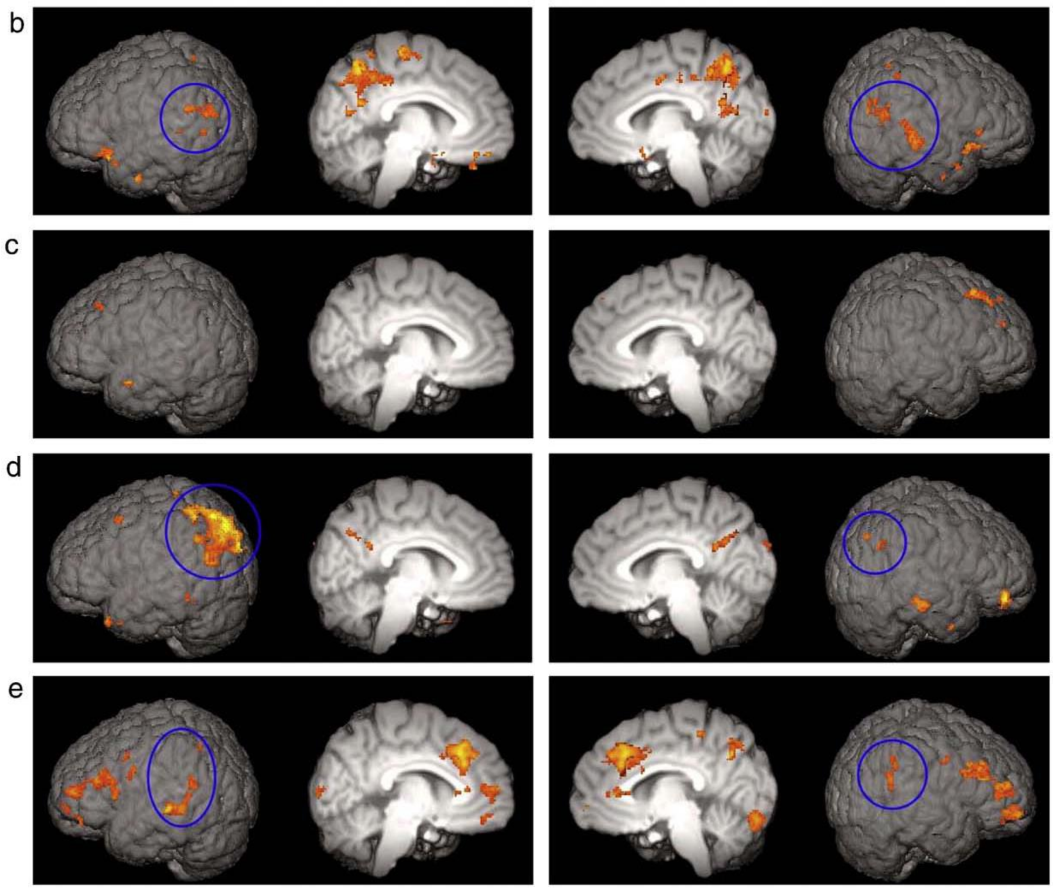
- Significantly atypical sulcal area pattern was also confirmed in kindergarteners with a familial risk of DD compared to controls.





Im *et al.*, 2016

Brain changes in response to three months of reading instruction in typical developing children and children at-risk for dyslexia.



Typical children at the start of kindergarten

At-risk children at the start of kindergarten

Typical children after three month of kindergarten

At-risk children after three month of kindergarten

(Yamada et al., 2012)

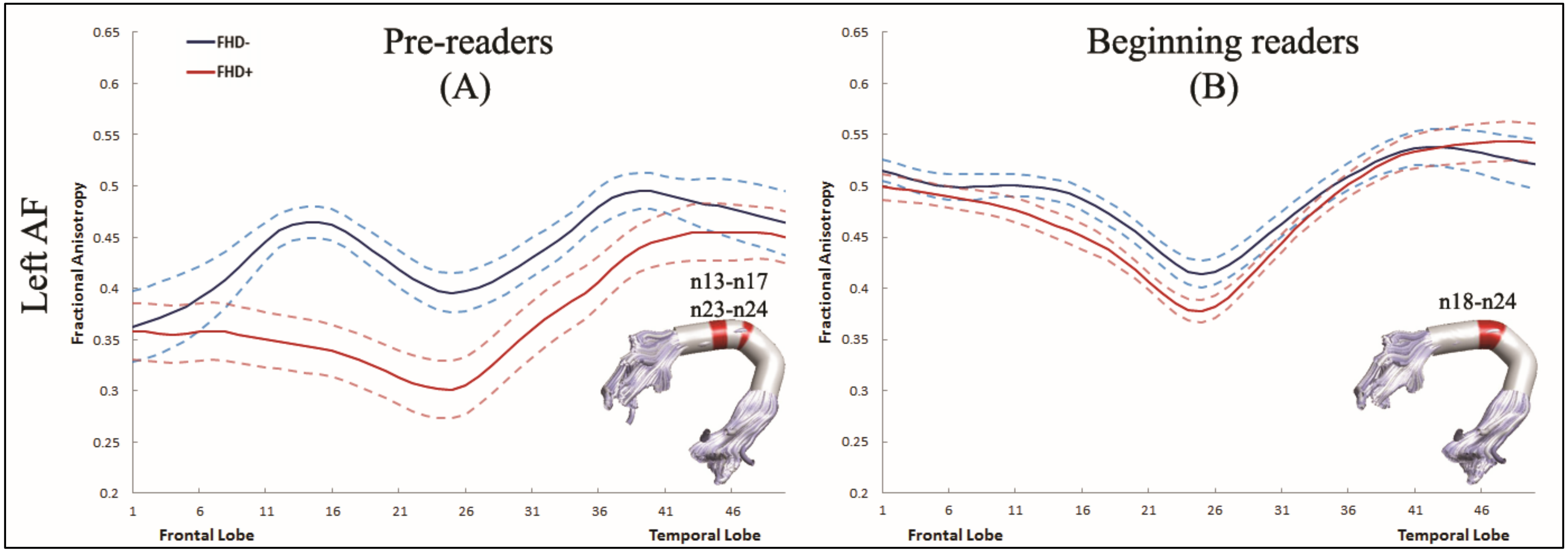
Development of Tract-Specific White Matter Pathways During Early Reading Development in At-Risk Children and Typical Controls

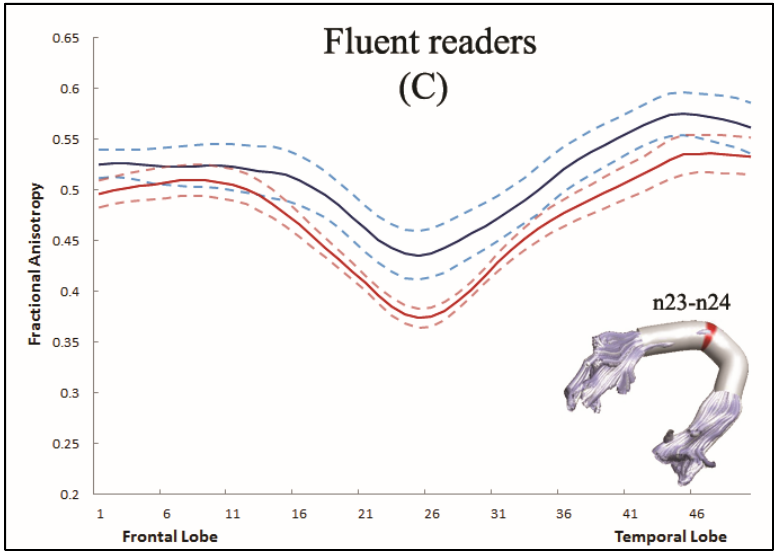
Yingying Wang[1,2,3], Meaghan V. Mauer[1], Talia Raney[1], Barbara Peysakhovich[1], Bryce L. C. Becker[1], Danielle D. Sliva[1] and Nadine Gaab[1,2,4]

- 78 healthy, native English-speaking children (45 FHD+, 33 FHD-)
- Among them, 45 children (23 FHD+ and 22 FHD-) had at least one scan and composed a longitudinal cohort.
- Three time points: re-reading, beginning reading, fluent reading

[Wang *et al.*, 2016]

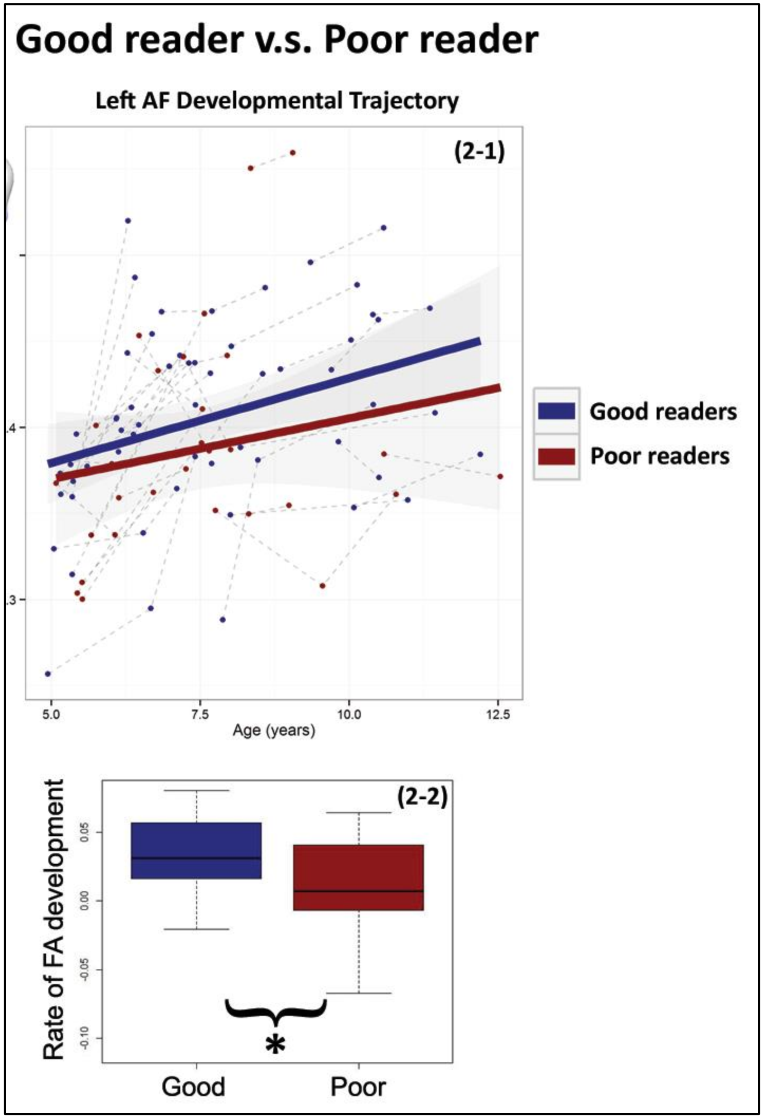
Cross-sectional results (n = 78): Arcuate Faciculus





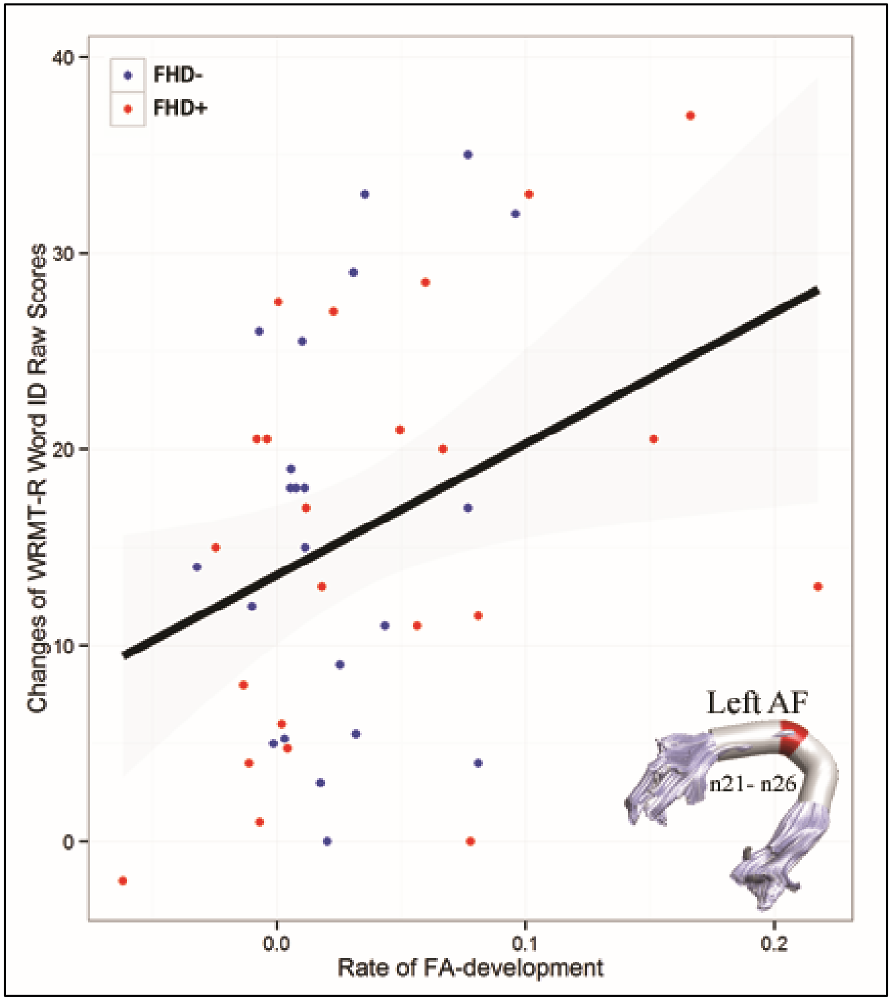
[Wang *et al.*, 2016]

Longitudinal Analysis: Development of the AF (n=45)

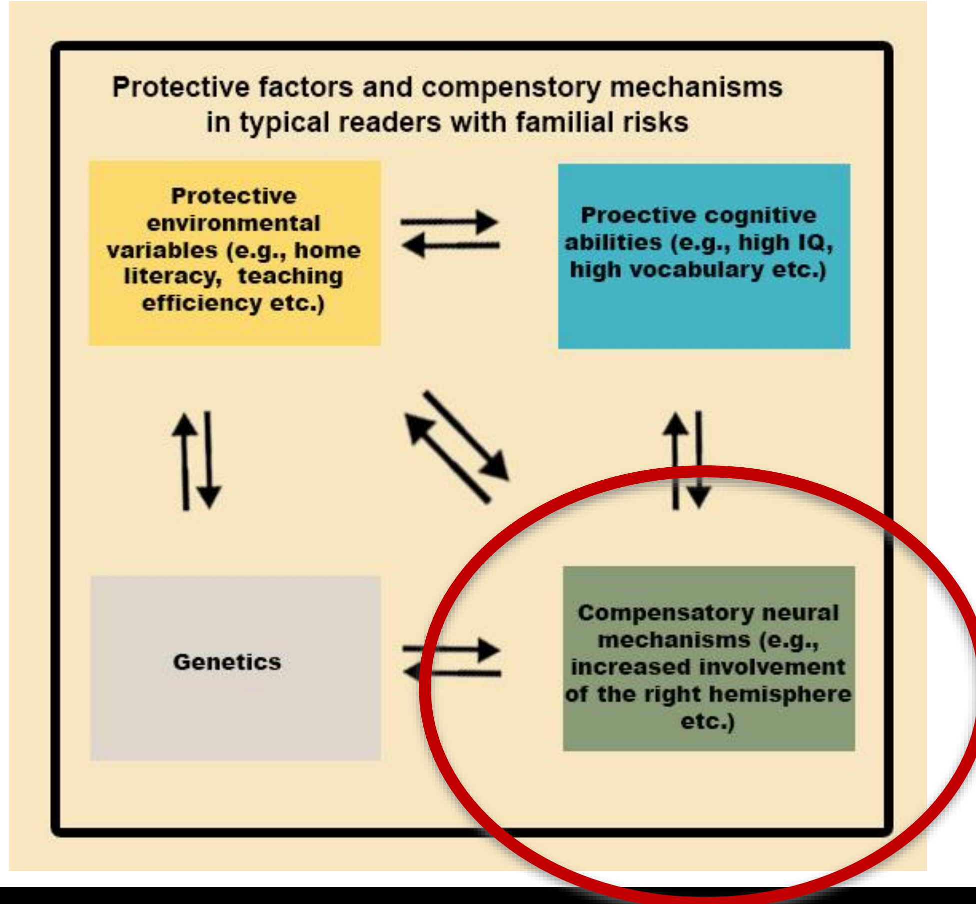


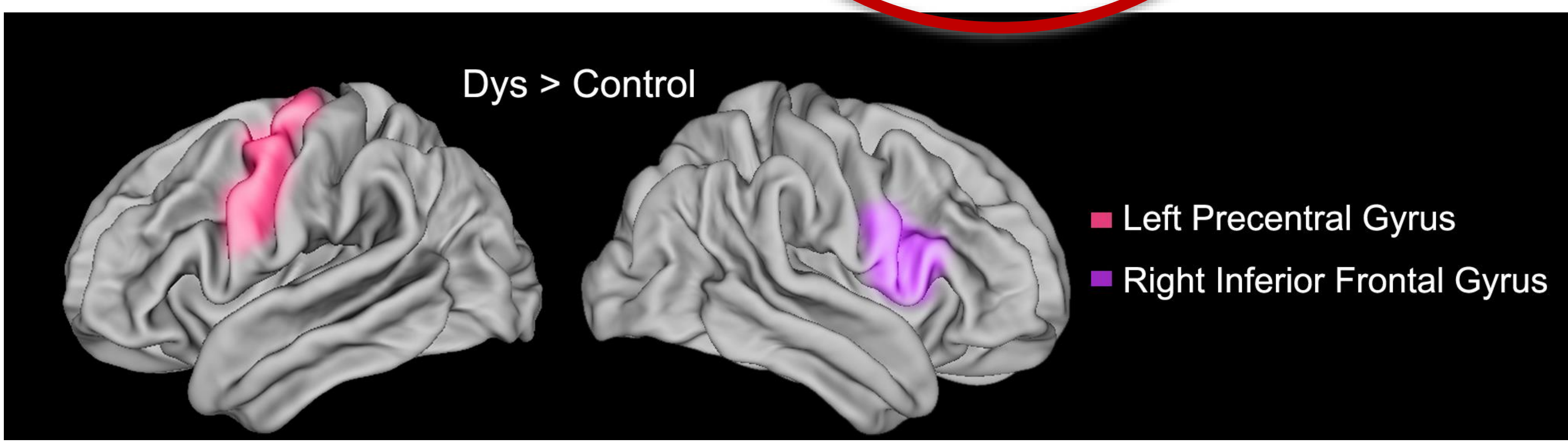
Wang *et al.*, in 2016

Linking FA development and reading development



Wang *et al*. 2016

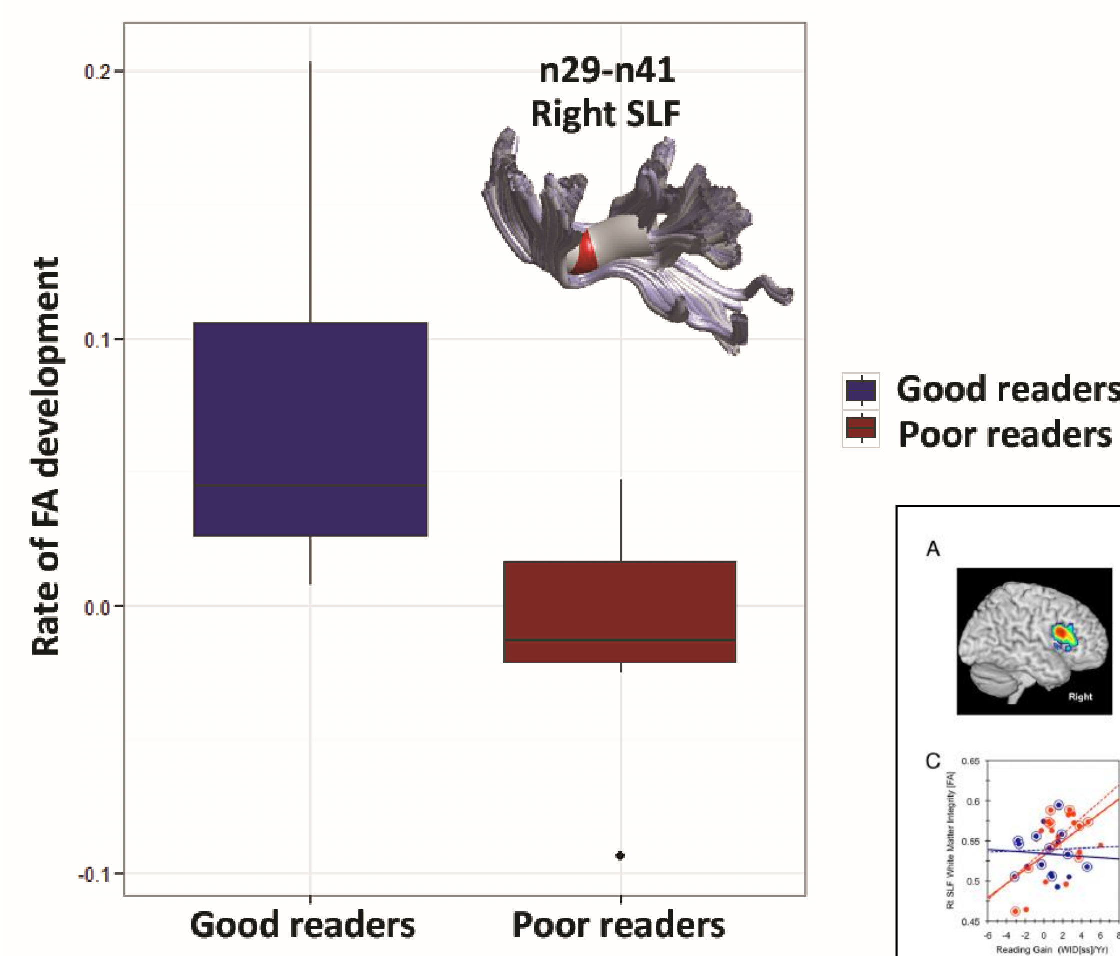


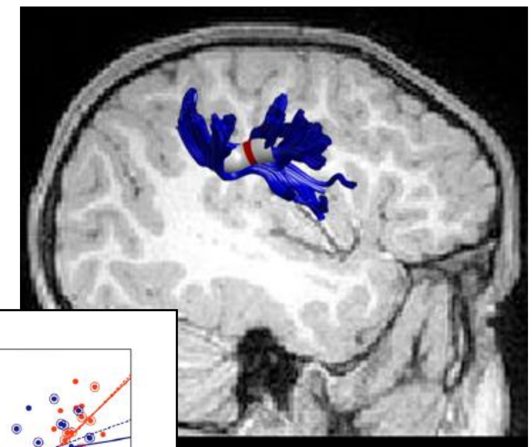


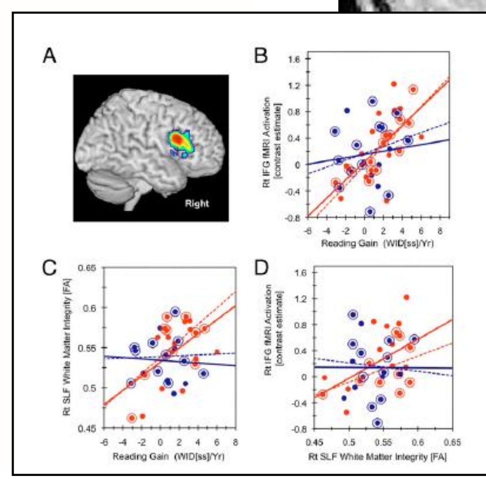
Ozernov-Palchik et al., 2016

Compensatory effects prior to reading onset?

Wang *et al.*, 2016





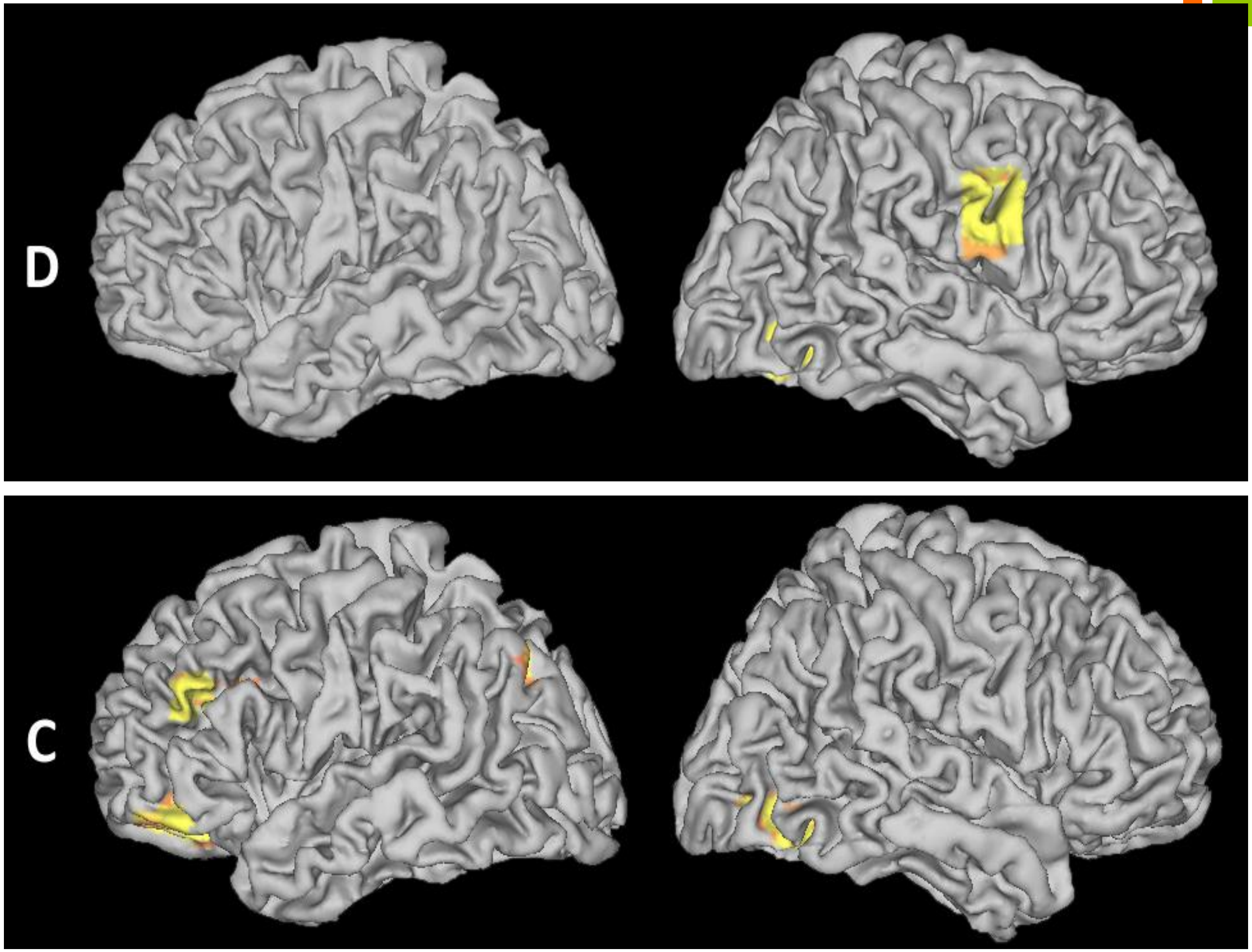


Of 21 FHD+ children, 11 developed into good readers, while 10 FHD+ developed into poor readers. The subsequent good readers show higher FA development rates in right SLF.

Correlations between home literacy environment and neural correlates of phonological processing

FHD+ > FHD-

FHD- > FHD+



Powers et al., 2016

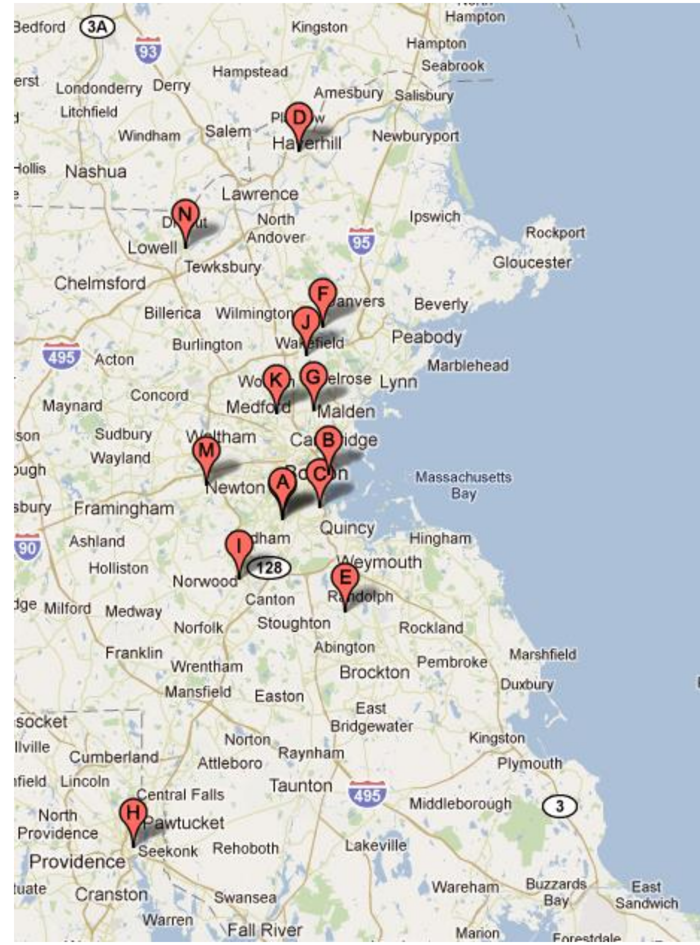
The READ Study

(Researching Early Attributes of Dyslexia)

- Screening of 1,433 children in 21 ‘partner’ schools in New England in 2011, 2012 and 2013. Highly diverse sample in terms of SES, race/ethnicity, and school type.
- 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

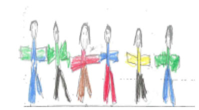
- 21 schools: inner-city charter schools, private, suburban district-run schools, and Archdiocese schools
- Free/reduced lunch eligibility from 0% to 80%
- Ethnically diverse student population (49% minority)
- Teacher professional developments and parent presentations conducted in all schools
- Brain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

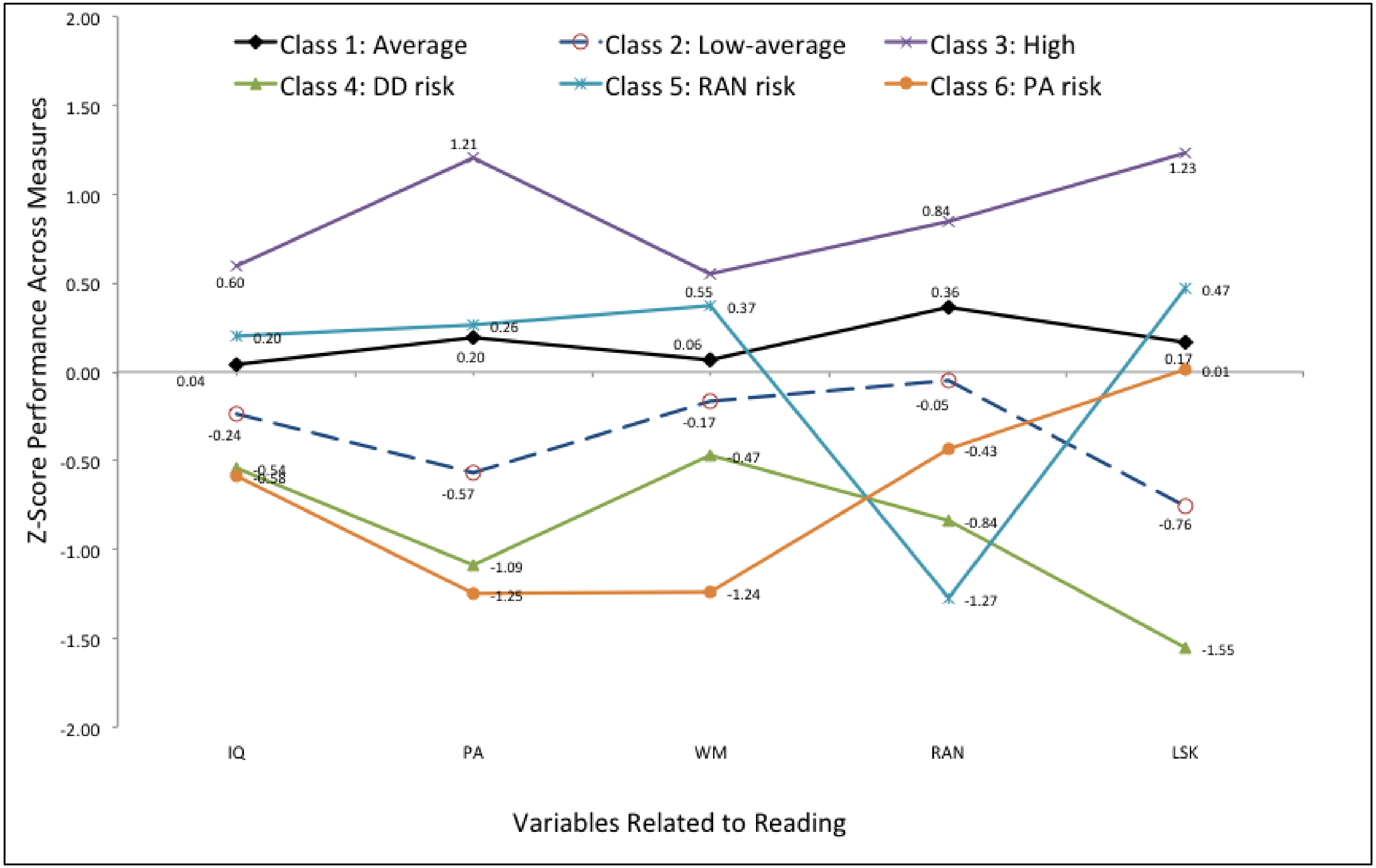
"…They were excellent presenters. The students had a wonderful time and were very engaged in the activities." (Teacher, Lowell Elementary)

"Your whole team was terrific in making the afternoons lots of fun and educational" (Parent, Hosmer Elementary)



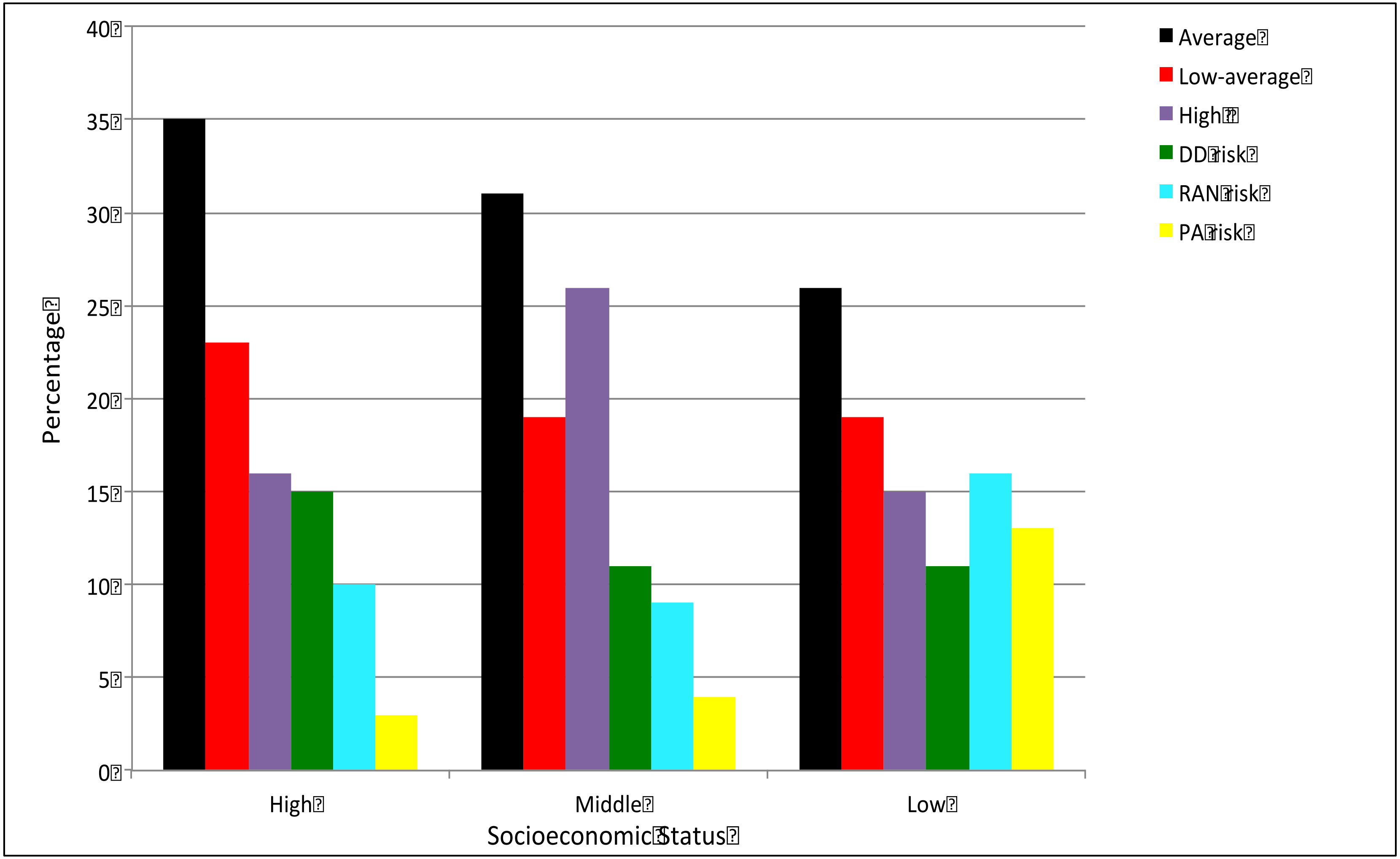
Six Distinct Cognitive Profiles of Early Reading

Ozernov-Palchik et al., 2016



Latent Profile analysis model for the Identification of Reading Subgroups: PA-phonological awareness, WM-working memory, RAN-rapid automatized naming, LSK-letter sound knowledge [n = 1,215 children].

Latent class distribution across SES type



Higher frequency of PA and RAN deficits in children from lower SES backgrounds

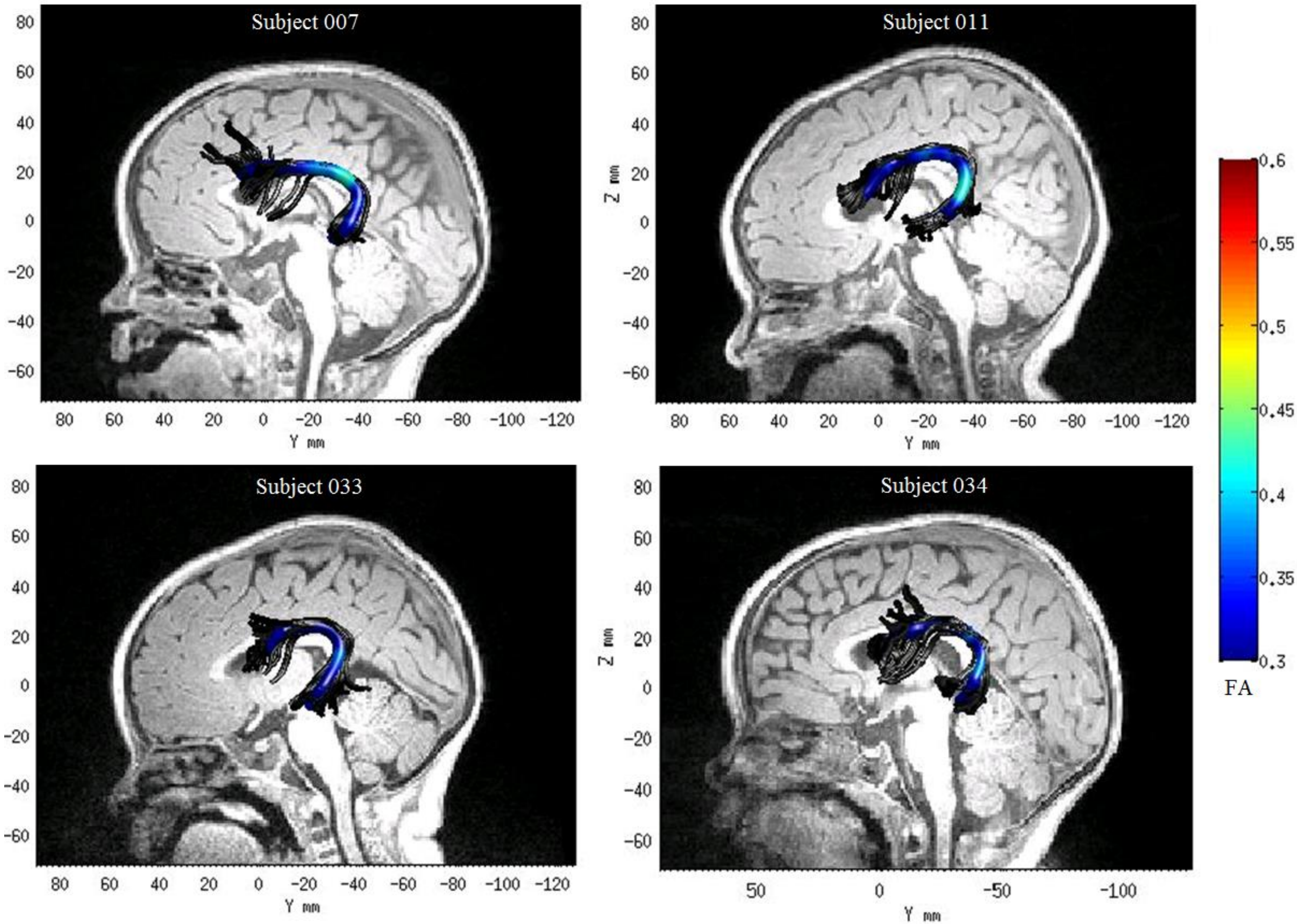
Ozernov-Palchik et al., in press

Investigating 4-12 months old infants with and without a family history of dyslexia

To date:
N=50 (30 FHD-/20 FHD+)
<u>Protocol:</u>
T1 MPRAGE
Resting state
DTI
FMRI (passive speech)

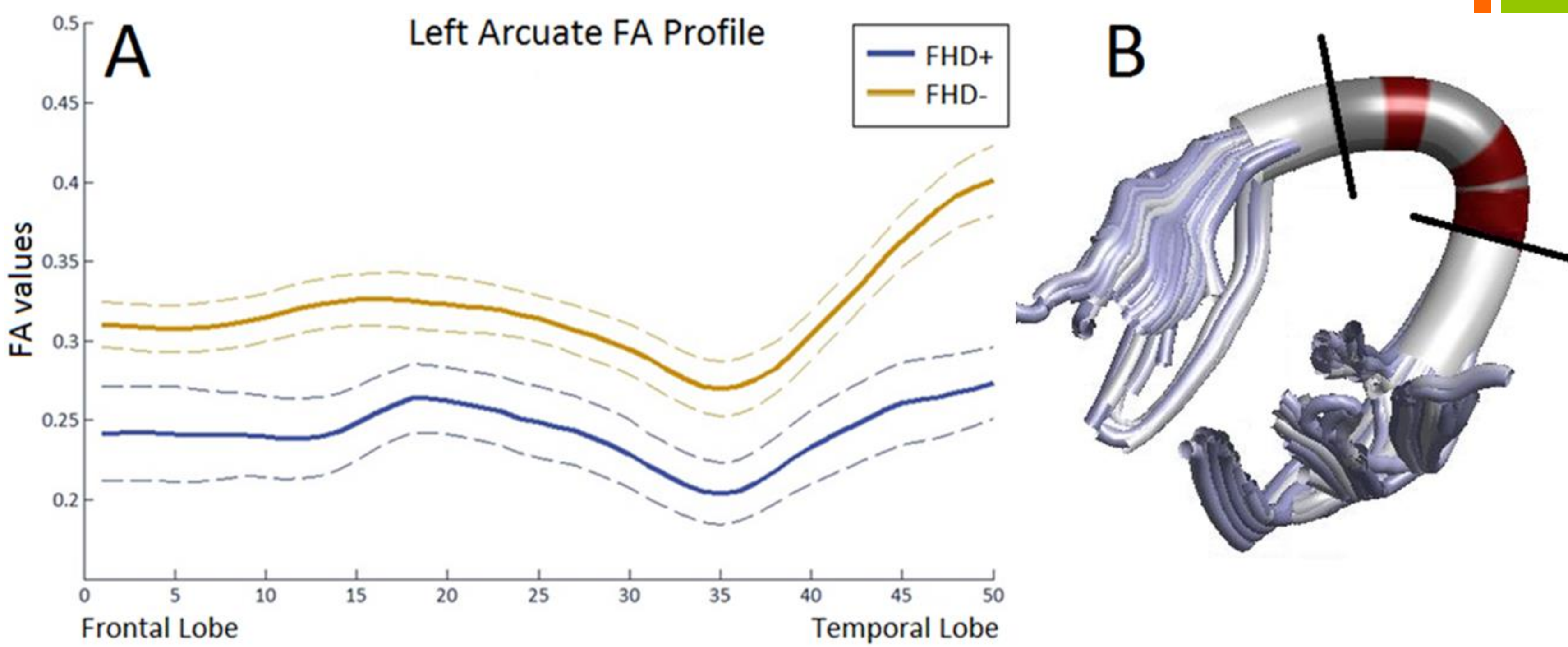
[Methods: Raschle *et al*., 2012]

AFQ



Subject 007
Subject 011
Subject 033
Subject 034
Z mm
Y mm
FA
0.6
0.55
0.5
0.45
0.4
0.35
0.3

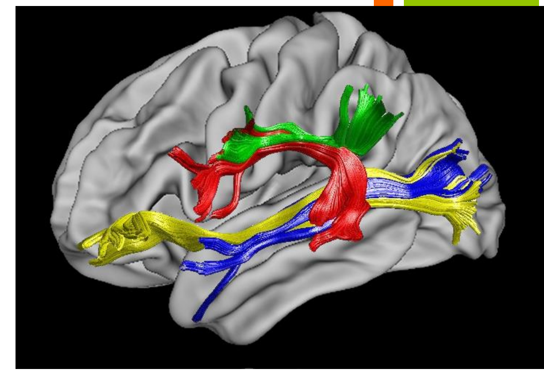
Automated Fiber Track Quantification in FHD+/FHD- infants

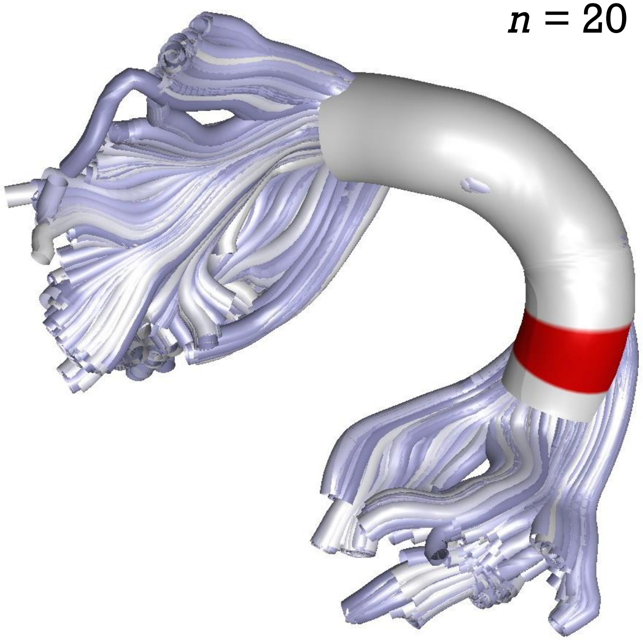


[A] FA values in FHD+ and FHD- infants at each of the 50 nodes.
[B] FHD+ infants exhibit significantly lower FA values compared to FHD- infants in red regions (all $p < 0.02$, controlled for multiple comparisons)

Langer *et al.*, 2017

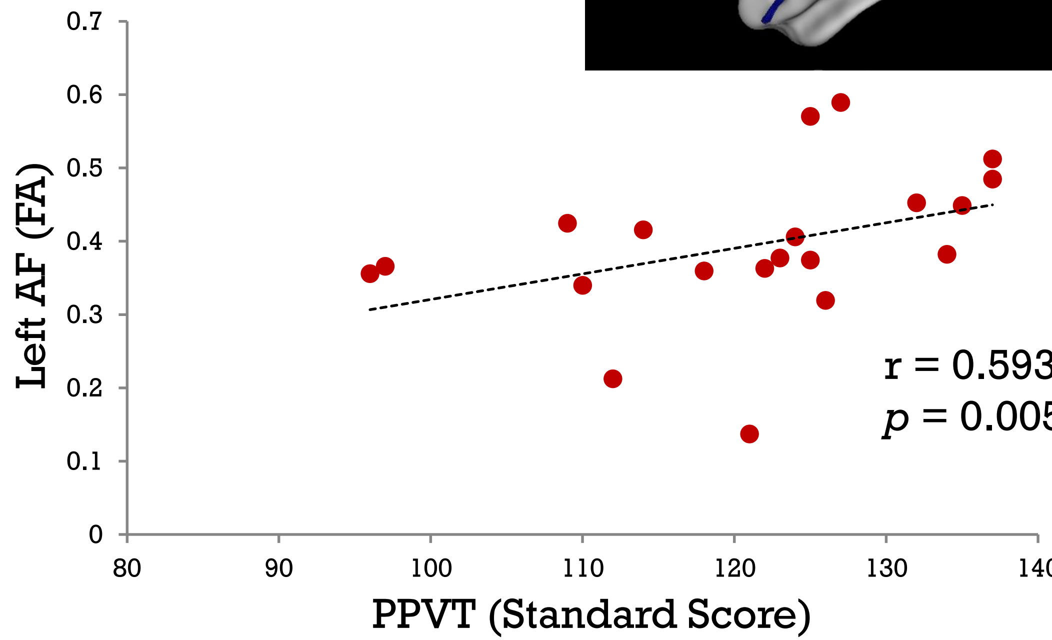
Examining the relationship between white matter tracts in infancy and subsequent language skills





n40 – n45

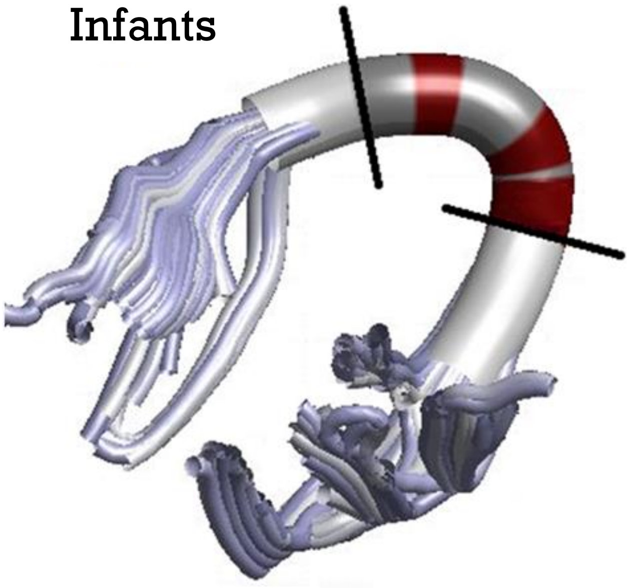
n = 20

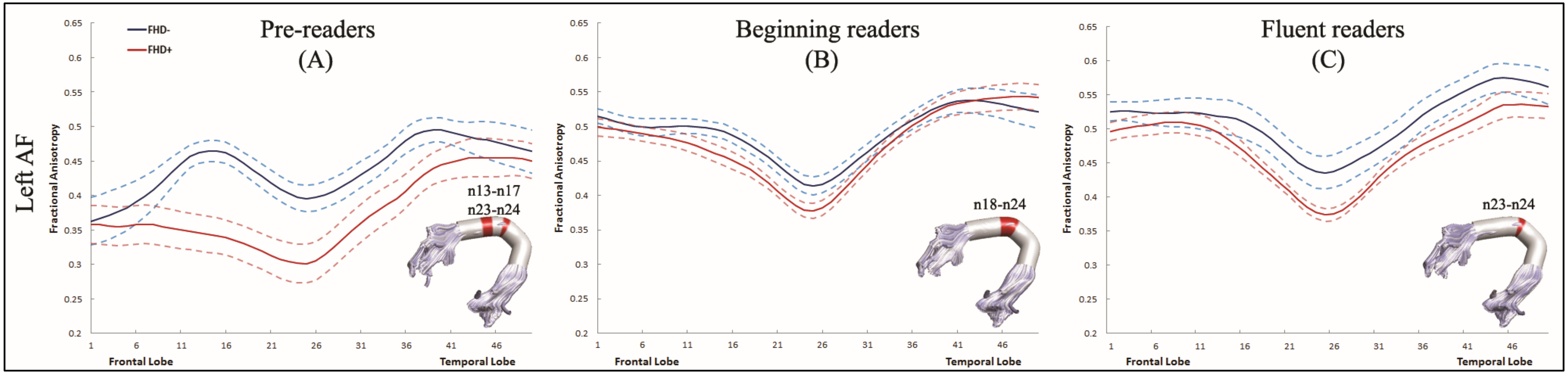


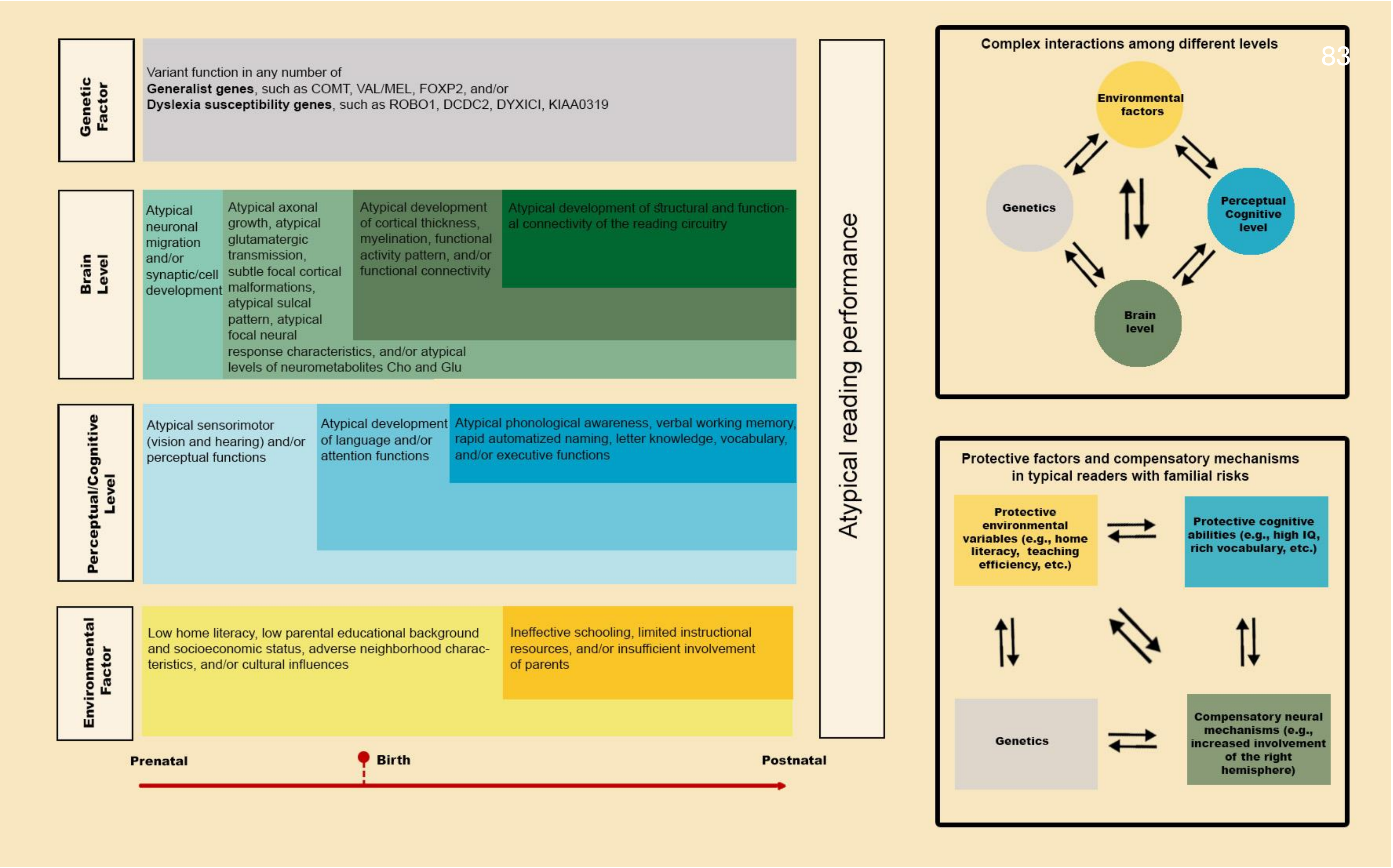
Positive significant relationship between FA in the left arcuate fasciculus and vocabulary knowledge

Atypical development of AF from infancy to late elementary school?

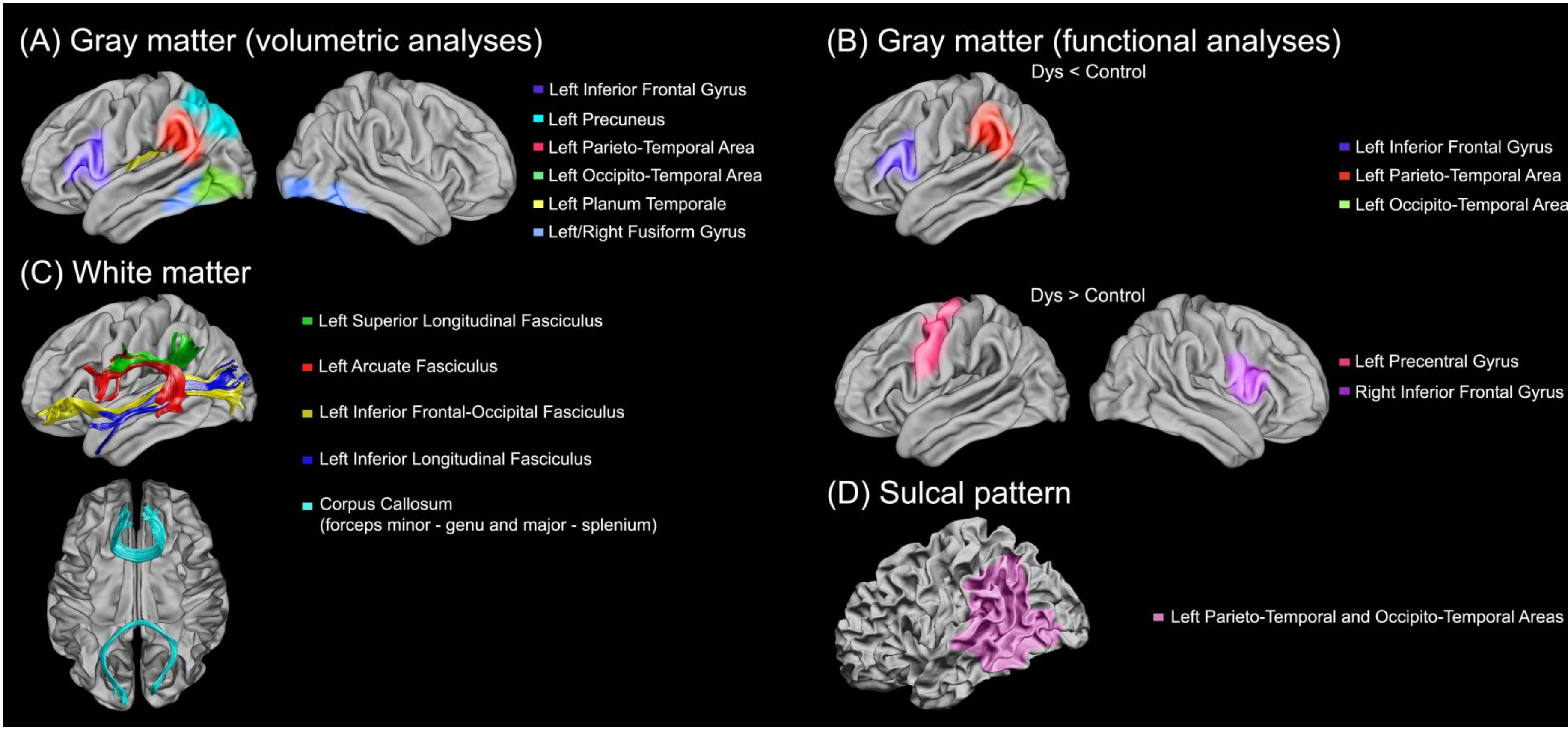
Infants







Ozernov-Palchik et al.,2016



Ozernov-Palchik et al; 2016

Solving the Dyslexia paradox

Early screening for dyslexia risk and accurate identification of students

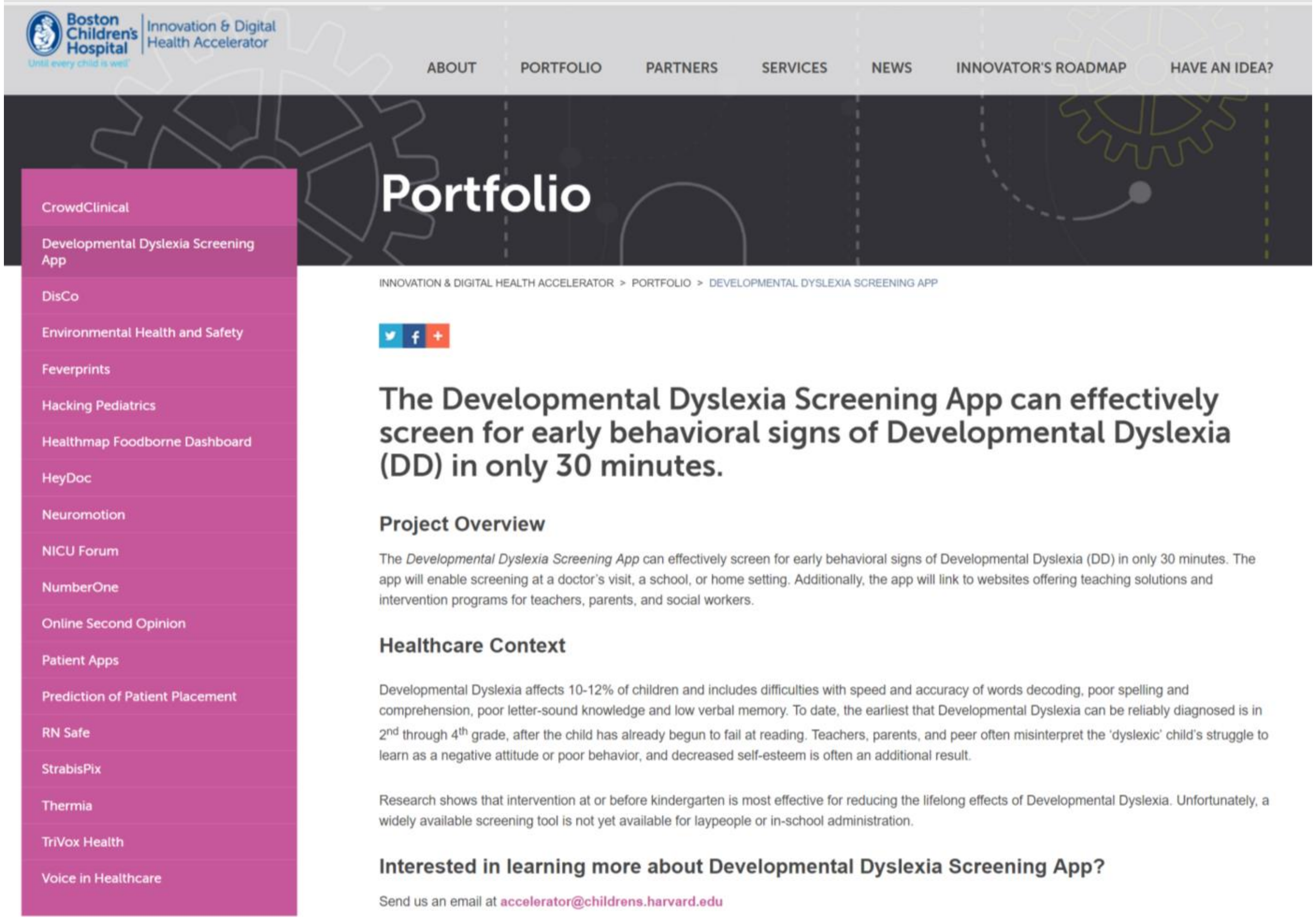
Evidence-based early intervention (ideally within general education)

'SUPPORT-MODEL'

Lower rates of dyslexia diagnosis and improved reading outcomes in children with dyslexia

Designing a Dyslexia Screening App

- Innovation and Digital Health Accelerator Grant 2016



Why and when should we screen?

- Dyslexia is a neurobiological disorder
- Brain alterations in dyslexia can be seen as early as infancy
- Brain plasticity decreases through childhood
- Children at-risk can be reliably identified
- Psychological and clinical implications can be prevented/minimized
- A screening tool will benefit all children, not just the ones who will develop dyslexia

Where should we screen?

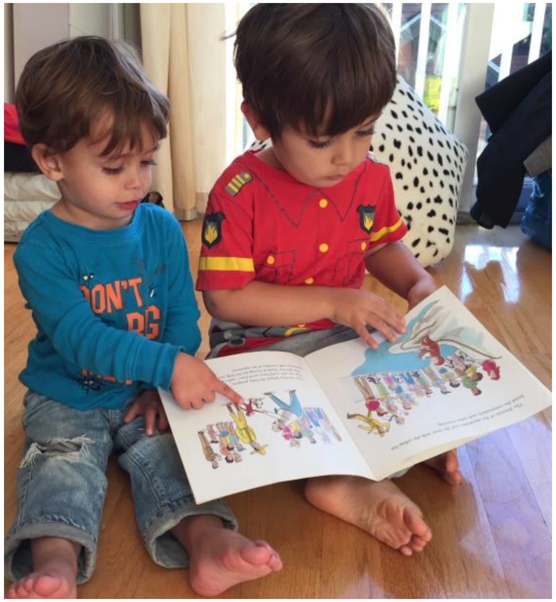
- Pediatrician's offices (e.g. at 4 or 5 year well visit)
- Children's homes
- Preschools/Day Cares
- Pre-kindergarten info sessions
- Summer Camps
- Children's Museum
- Speech and Language Therapy/Occupational Therapy sessions
- Etc.

SCREENED

What should early screening look like?

We recommend eight key characteristics when determining an optimal screening battery for an individual classroom, school, or district. The first letters of these characteristics spell the acronym SCREENED.

- **S** hort
- **C** omprehensive
- **R** esourceful
- **E** arly
- **E** SL/Dialect Inclusion
- **N** eurobiology/Genetics
- **E** vidence-based response to screening
- **D** evelopmentally appropriate



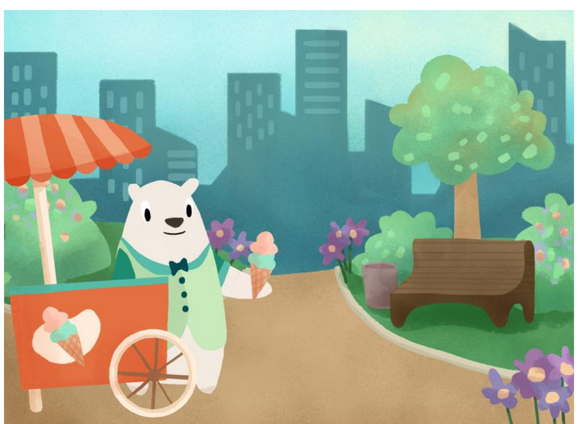
Gaab, 2017 (IDA, Examiner)

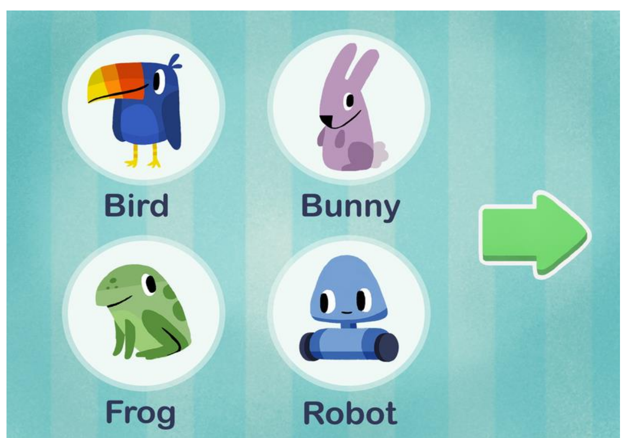
How should we screen?

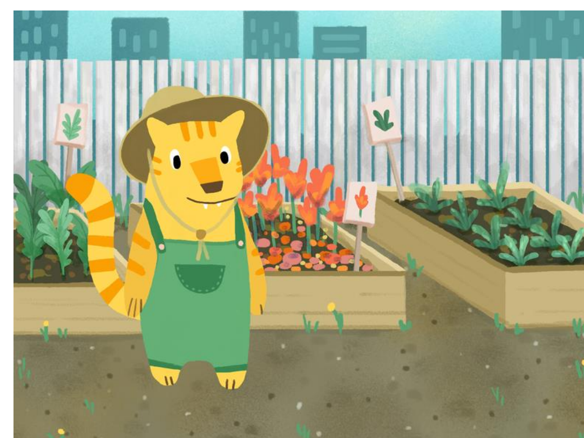
- Integrating existing predictive dyslexia assessments into a mobile platform

- Screening for early indicators of dyslexia in children as young as four years of age providing the opportunity to intervene during a period of increased brain plasticity.

- The App will offer a list of resources if a risk is detected. It will further link to resources that offer teaching solutions and intervention programs for teachers, parents and social workers to address the instructional needs of children at-risk (evidence-based response to screening).







Overview

- Atypical language development
- Neurobiology of atypical language development
- Atypical reading development/Developmental Dyslexia
- Theories of Developmental Dyslexia
- Neurobiology of atypical reading development
- Remediating the atypical reading brain
- Early identification of children at risk for reading impairments
- Challenges and implications for educational practice and policy

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.

Educational and clinical implications

- Early identification may reduce the clinical, psychological and social implications of DD.
- Understanding the complex etiology of specific learning disabilities and their co-occurrences will be essential to underpin the training of teachers, school psychologists, and clinicians, so that they can reliably recognize and optimize the learning contexts for individual learners→ personalized medicine/education (Butterworth & Kovas, 2013)
- 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.
- Improved psycho-social development (reduced child stress, parental stress, improved overall family dynamic).

Can Neuroimaging inform educational practice and policy in reading disorders?

- Can neuroscience inform a definition of dyslexia?
- Neurobiological support for existing theories?
- Can neuroimaging assist to determine the optimal window for intervention/Predicting intervention outcome?
- Can neuroimaging help to distinguishing genetic versus environmental factors that may inform interventions ?
- The knowledge about underlying mechanism may inform development of intervention strategies (especially in early childhood)
- Can neuroimaging help to characterize subtypes of reading disabilities?
- Can neuroimaging assist with determining school readiness?
- Which brain learns best under which circumstances?

(e.g. Ozernov-Palchik et al., 2016; Black et al., 2015)

The Typical and Atypical Reading Brain

H-126 Typical and Atypical Neurodevelopment
September 29th, 2014

"Children are wired for sound, but print is an optional accessory that must be painstakingly bolted on"

Steven Pinker