Center for the Study of Learning

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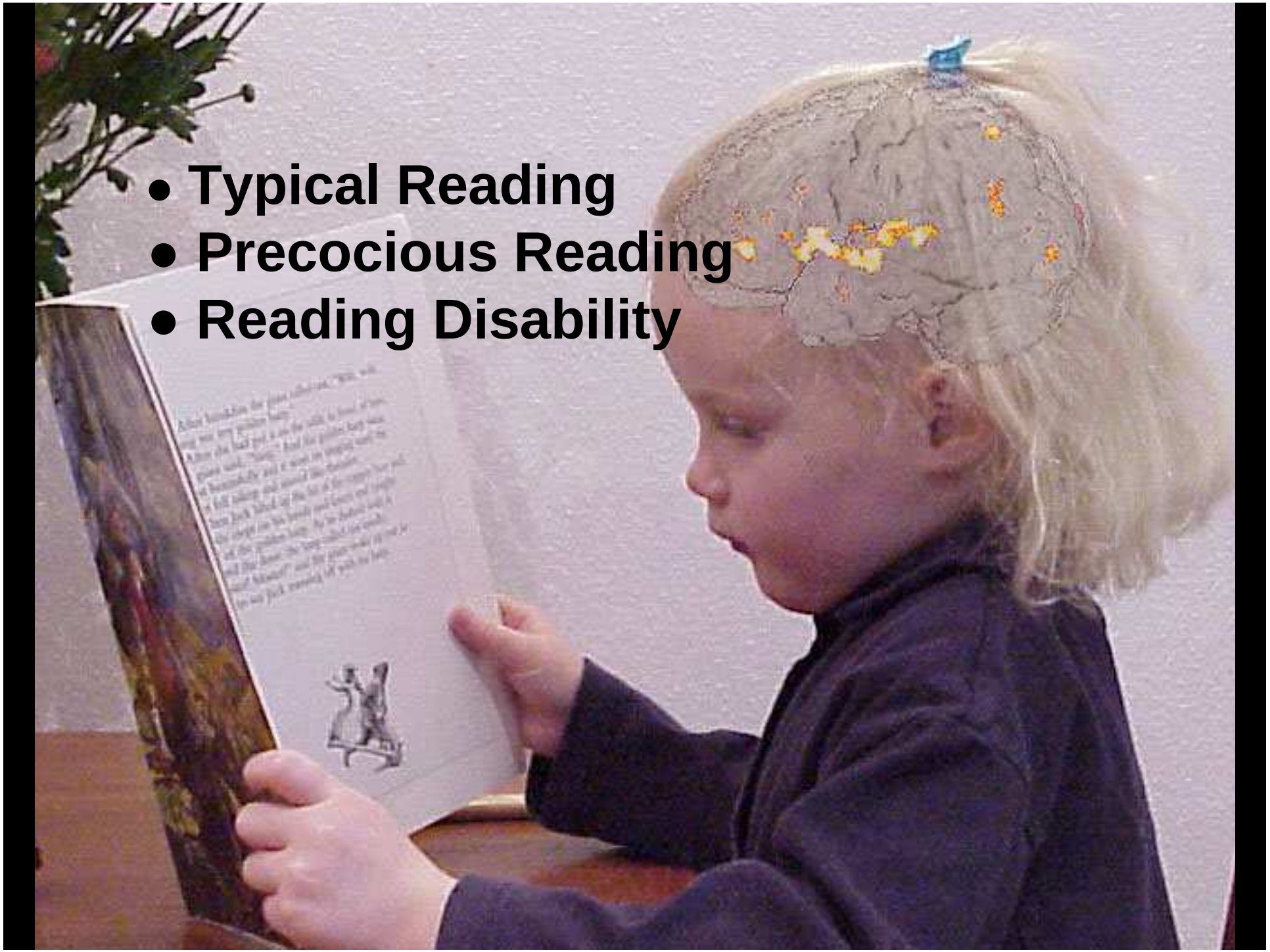
First use of alphabet - 1800 B.C.


• Typical Reading
• Precocious Reading
• Reading Disability

Learning to Read

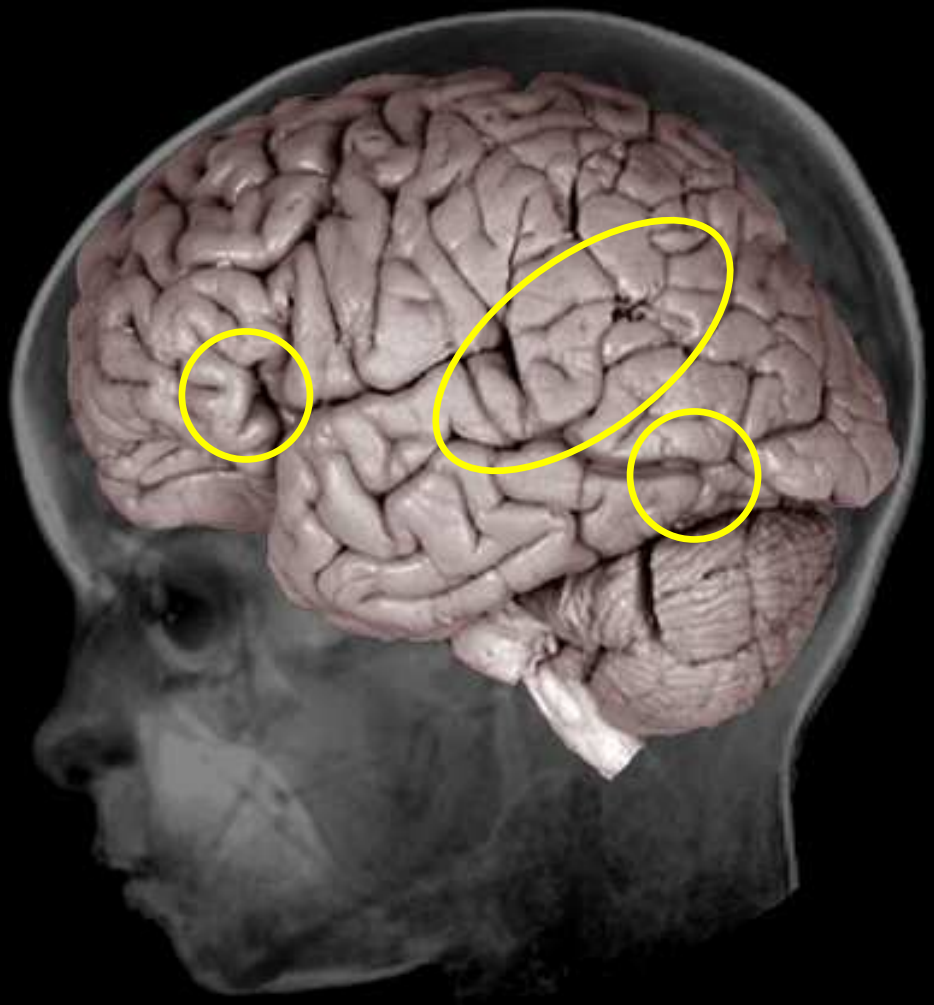
- Phases of reading acquisition (Ehri, 1992)
  - Pre-alphabetic- visual
  - Partial alphabetic- phonological cues
  - Full alphabetic- decoding
  - Consolidated Alphabetic- chunking, analogy
- Phonological processing abilities are critical (Wagner and Torgesen, 1987)

Research Questions

- What is the neural basis of visual word processing in healthy children?
- How does the neural basis of word processing change during schooling?
- What is the relationship between these neural systems and phonological skills?

The neural basis of reading

- Left inferior frontal gyrus
- Left temporo-parietal cortex
- Left infero-temporal cortex



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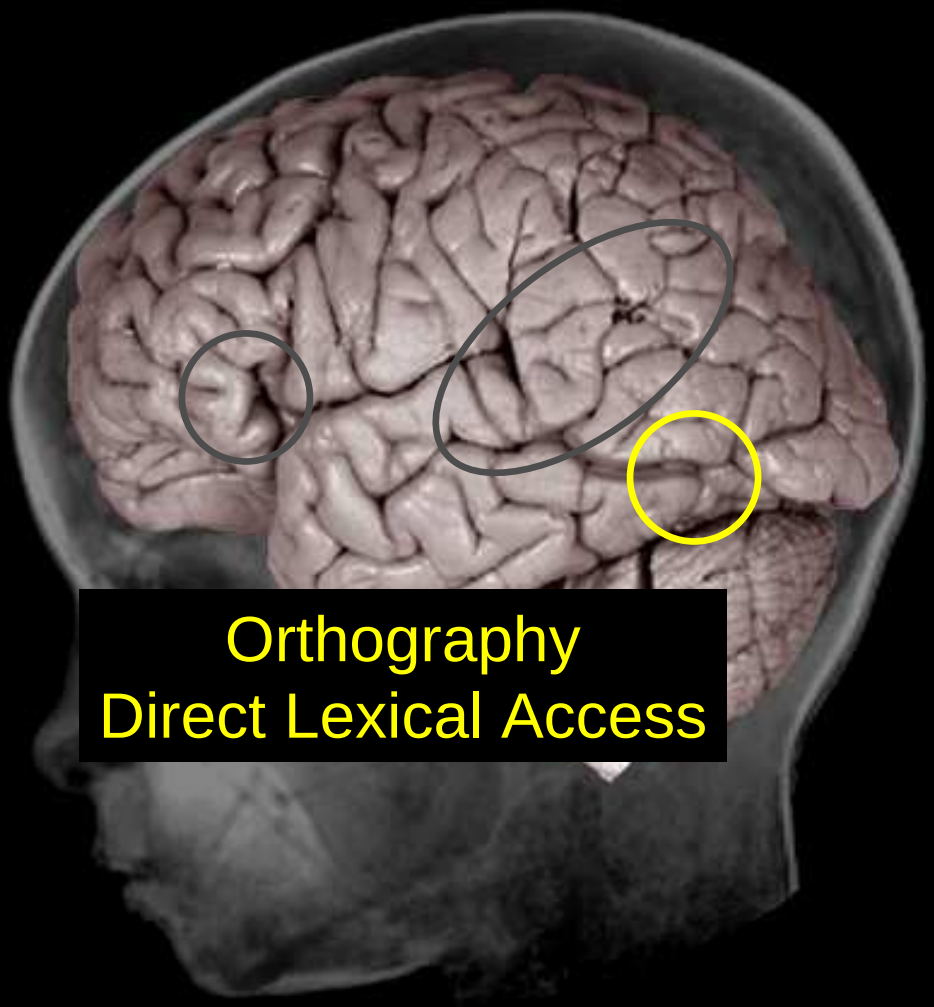

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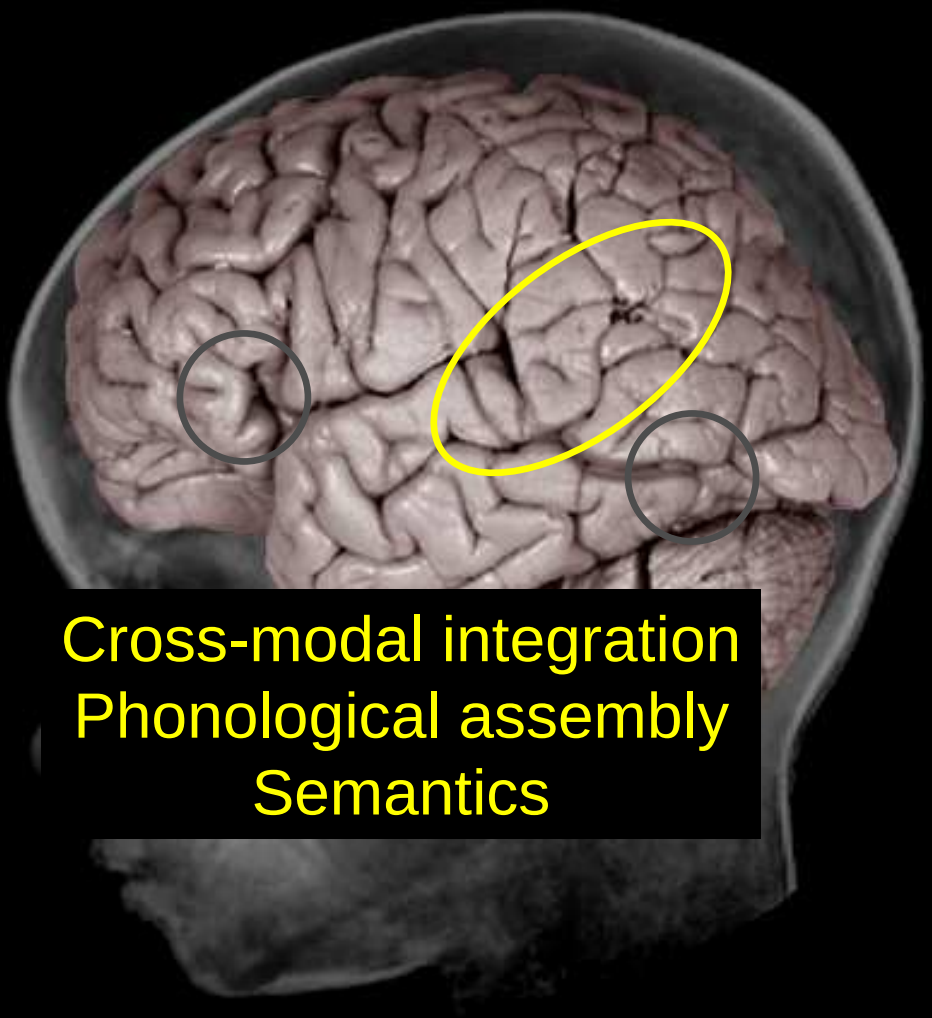

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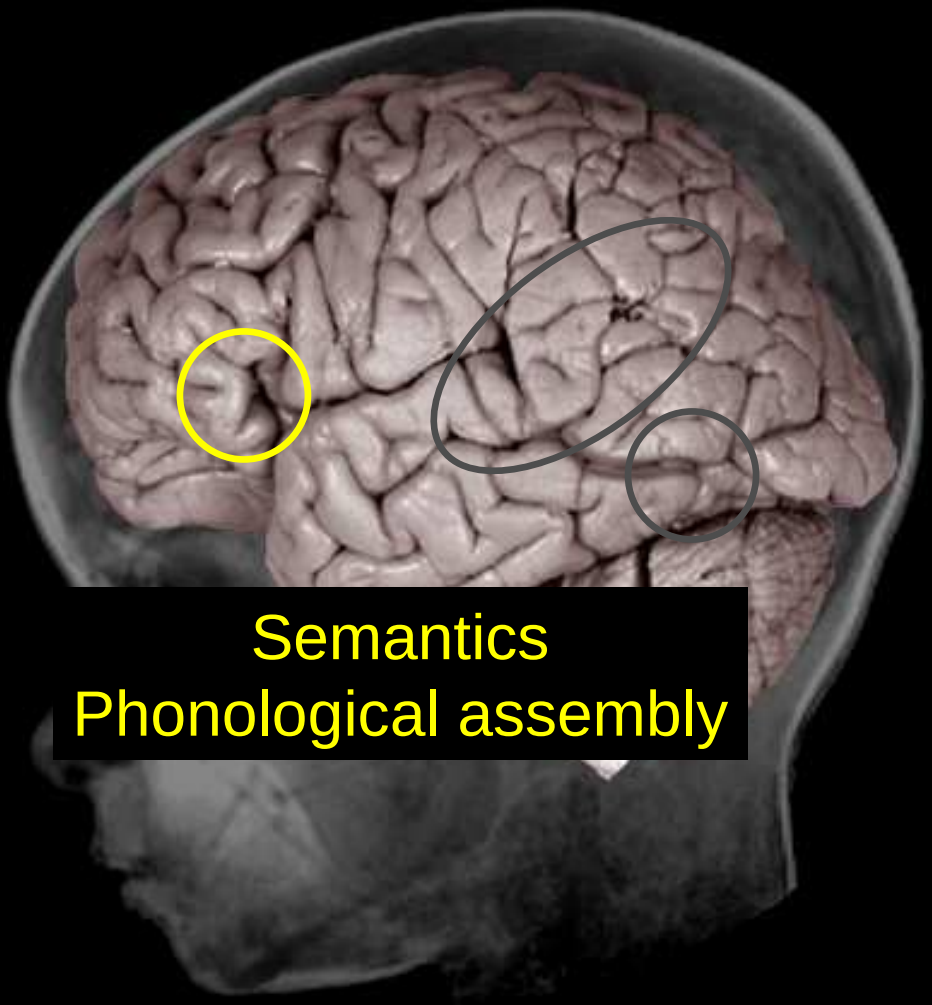
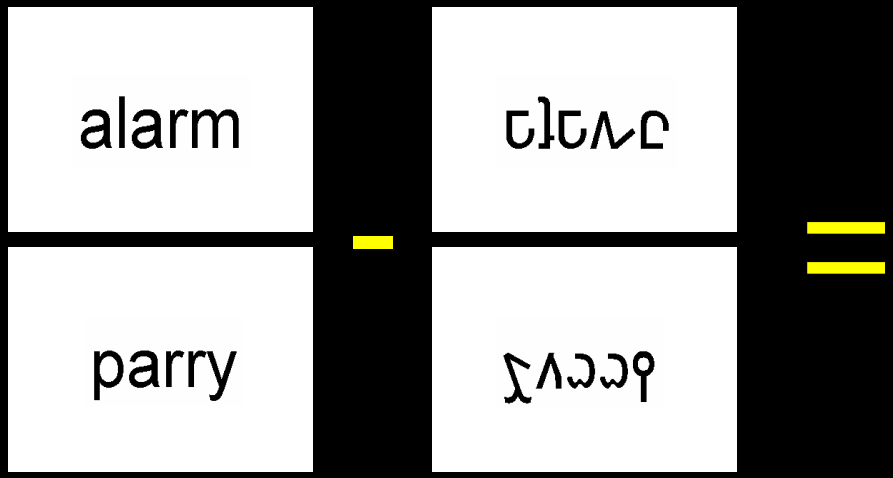


I told you not to read this, didn’t I?

Implicit Word Processing

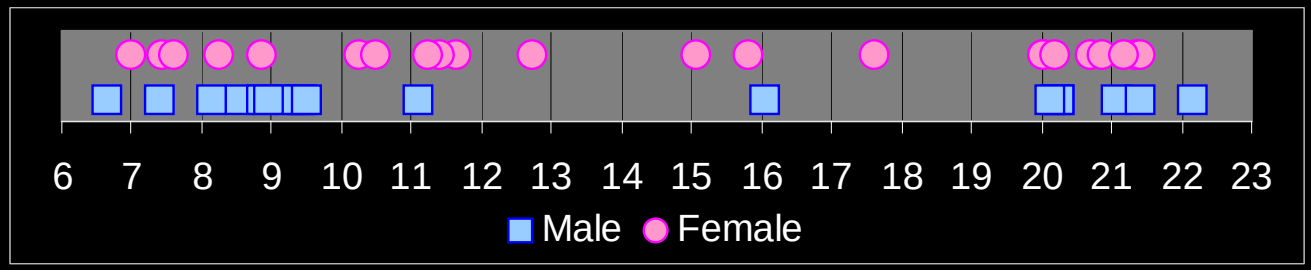
alarm

parry

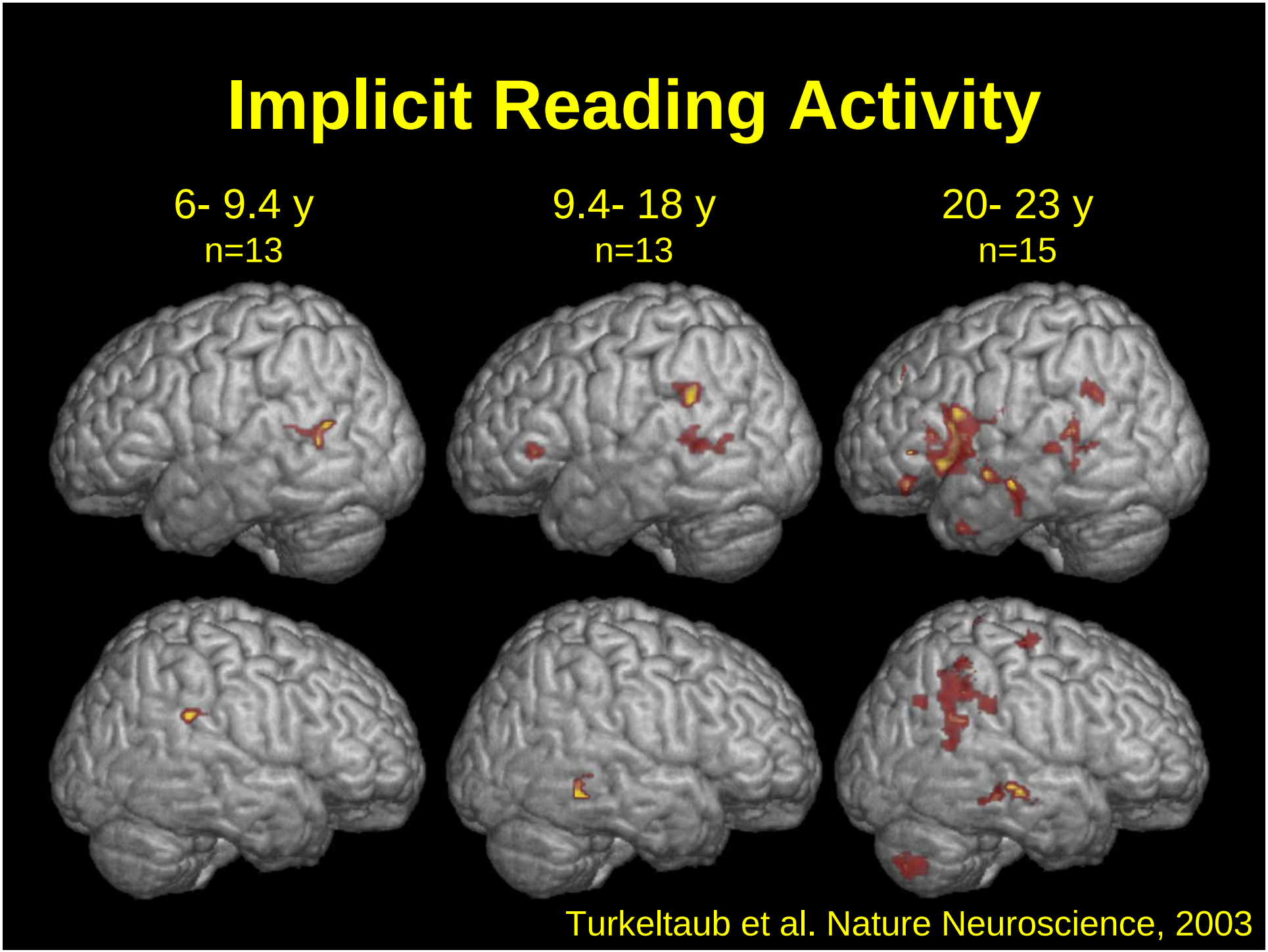


Adapted from Price et al, 1996

41 normal subjects

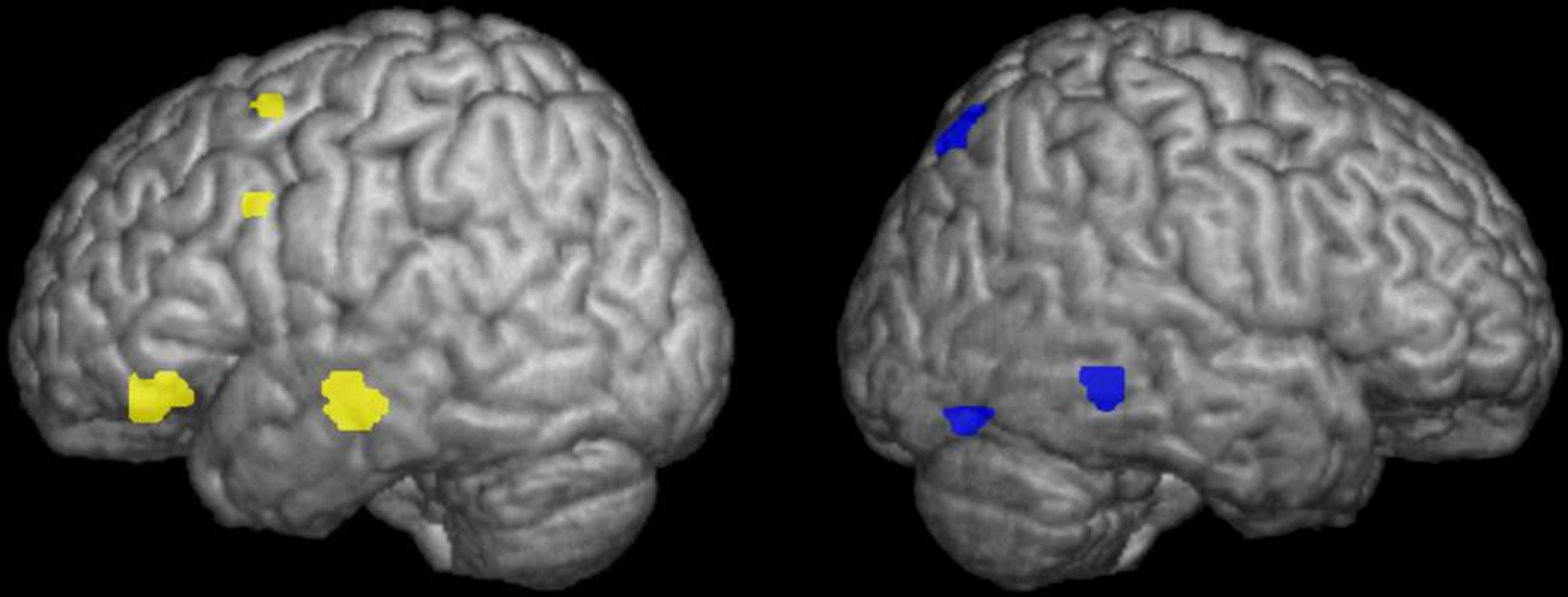


Implicit Reading Activity



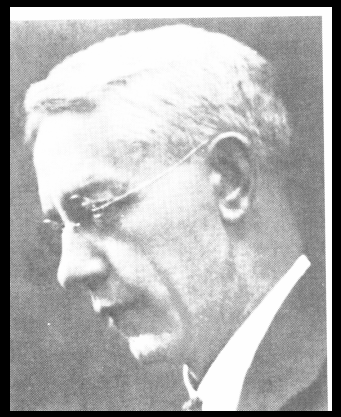
Turkeltaub et al. Nature Neuroscience, 2003

Developmental Changes in Activity



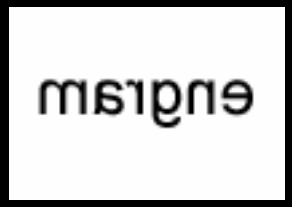
p< .001, peak p< .0001

Samuel Orton
1925



“In the process of early visual education… the storage of memory images of letters and words occurs in both hemispheres…. the process of learning to read entails the elision from the focus of attention of the confusing memory images of the nondominant hemisphere”

engram

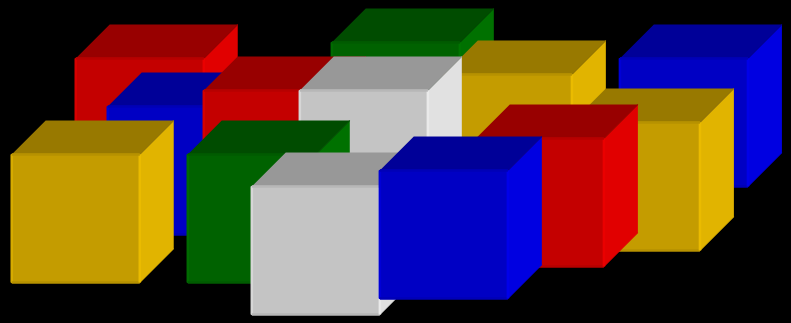


Phonological Processing and Reading

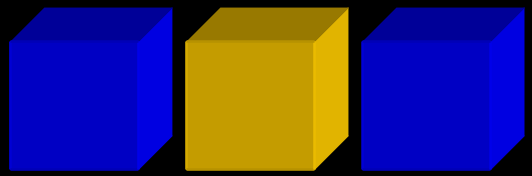
- **Types of phonological processing (Wagner & Torgesen, 1987)**
  - **Phonemic Awareness (LAC)**
  - **Phonological Naming (RAN)**
  - **Working Memory (Digit Span)**
- **Subtypes of dyslexia are associated with these types of functions**
- **Are these abilities associated with different brain regions?**

Phonemic Awareness

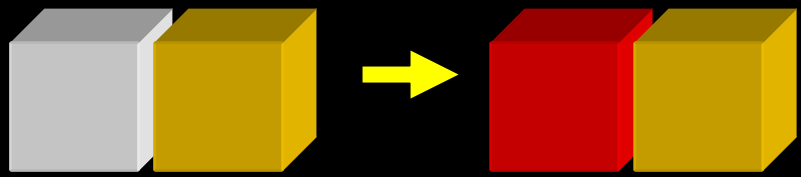
Lindamood Auditory Conceptualization Test (LAC)



"Show me /p/ /t/ /p/"

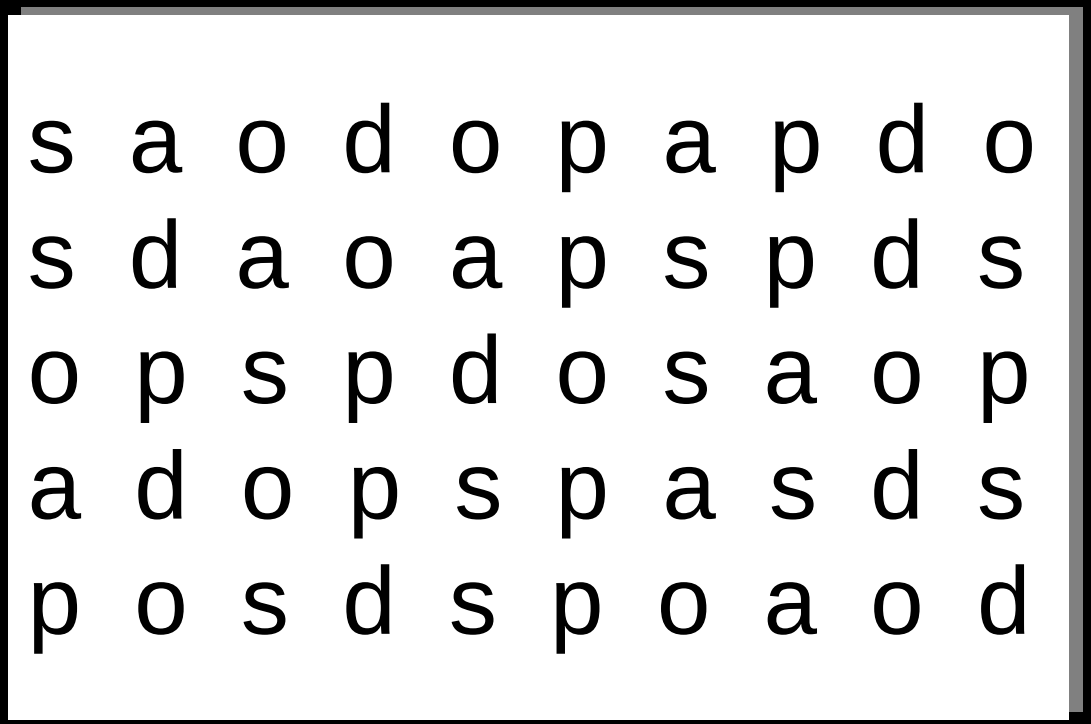


"If this says 'eth', show me 'ith'



Phonological Naming

Rapid Automatized Naming Test (RAN)

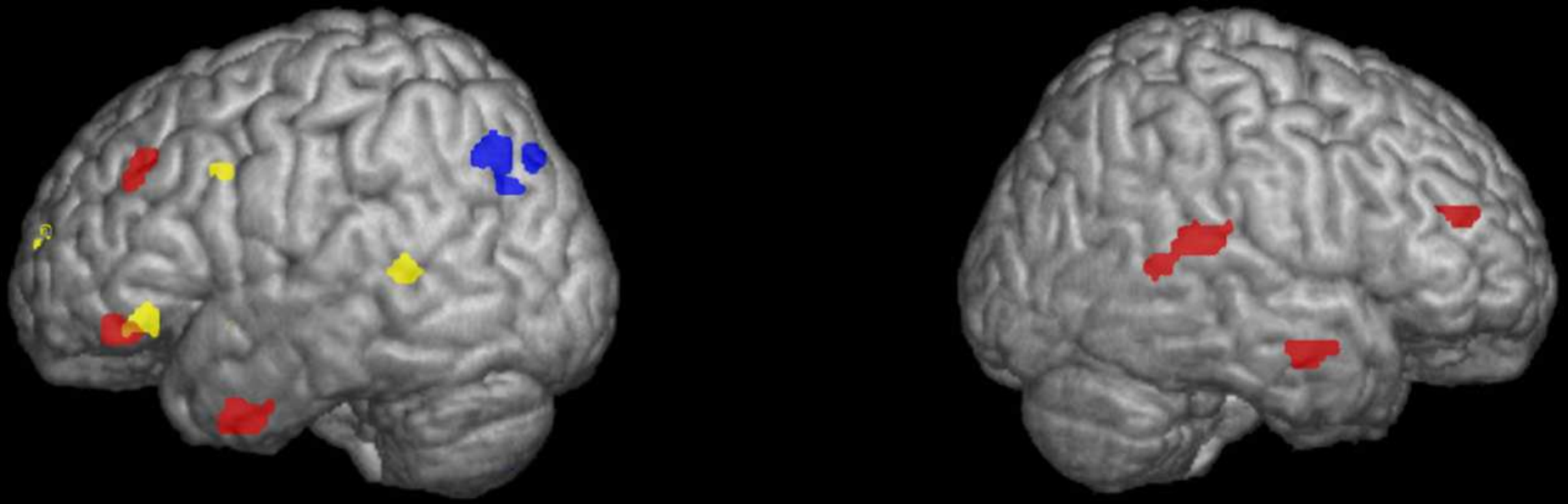


Working Memory

Digit Span

“3 8 2 4”
“7 4 6 2 5”
“9 2 3 6 1 8”
“5 3 8 2 7 4 6”
“2 5 4 3 2 8 9 4”

Correlations with Phonological Processing



Phonemic Awareness
Phonological Naming
Working Memory

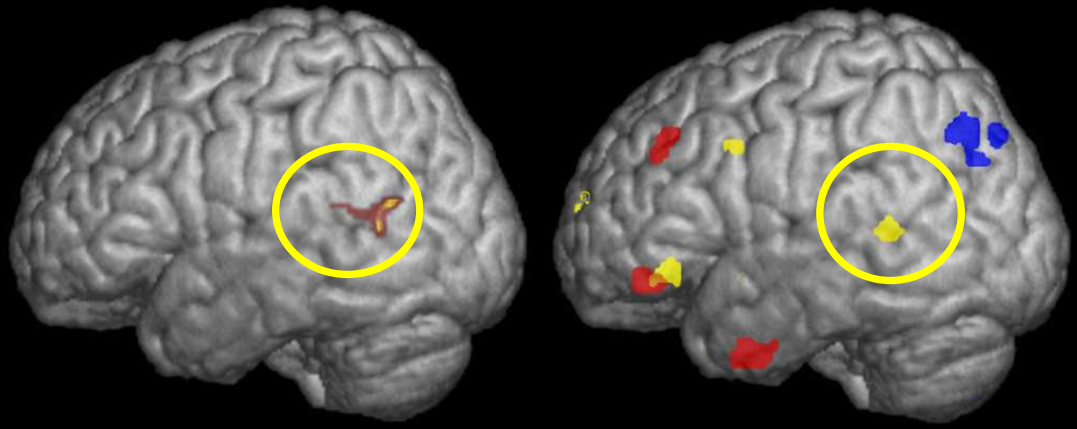
p< .005, peak p< .0005

Turkeltaub et al. Nature Neuroscience, 2003

Conclusions

Young Readers

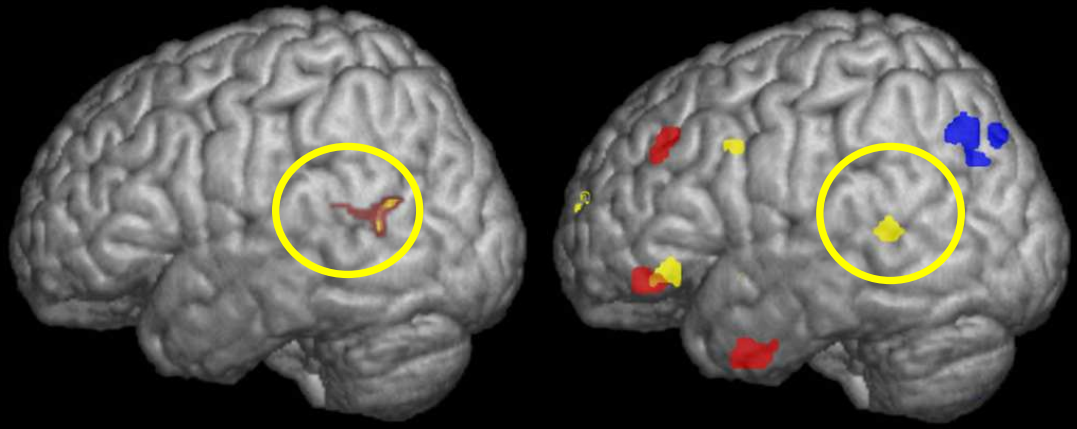
Phonology



Young readers activate left temporoparietal cortex, related to phonological awareness

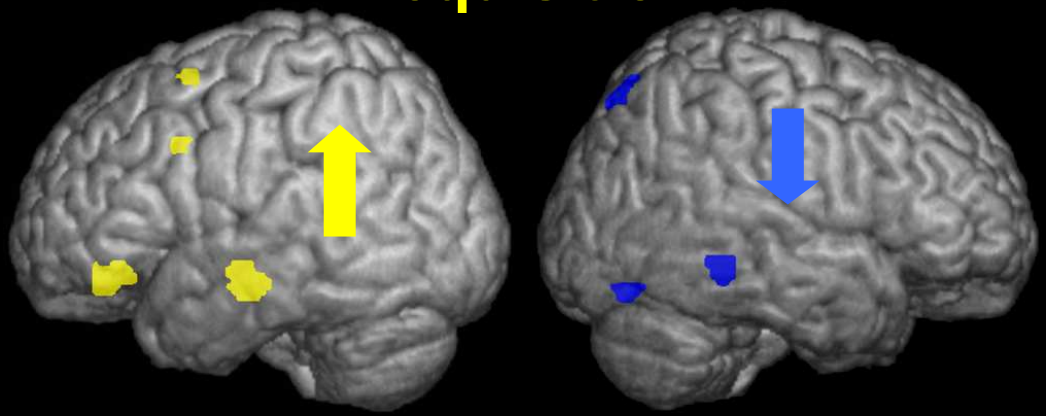
Conclusions

Young Readers **Phonology**



Young readers activate temporoparietal cortex, related to phonological awareness

Reading Acquisition

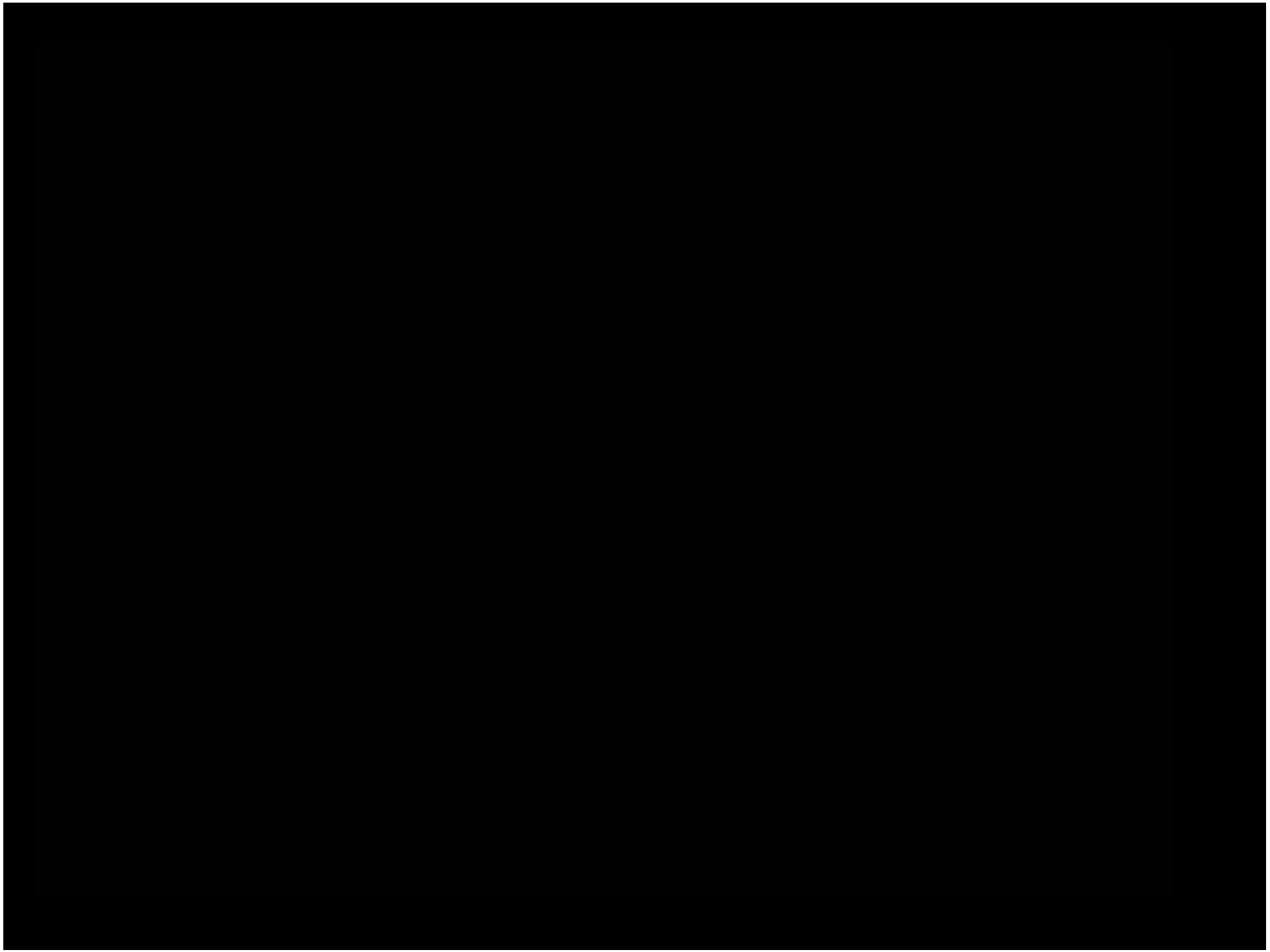


Reading acquisition=

Right posterior cortex (nonlinguistic visual)

Left frontal & temporal (phonology, semantics)

The neural basis of precocious reading acquisition: fMRI case study of hyperlexic reading



Hyperlexia

- Developmental disorder of communication (usually autism spectrum)
- Extremely precocious reading learned very early without explicit instruction
- Reading scores above expectation, with comprehension commensurate with verbal ability
- Incidence ≈ 2 / 10,000 (Burd et al., 1985, Yeargin-Allsopp, 2003)

Ethan

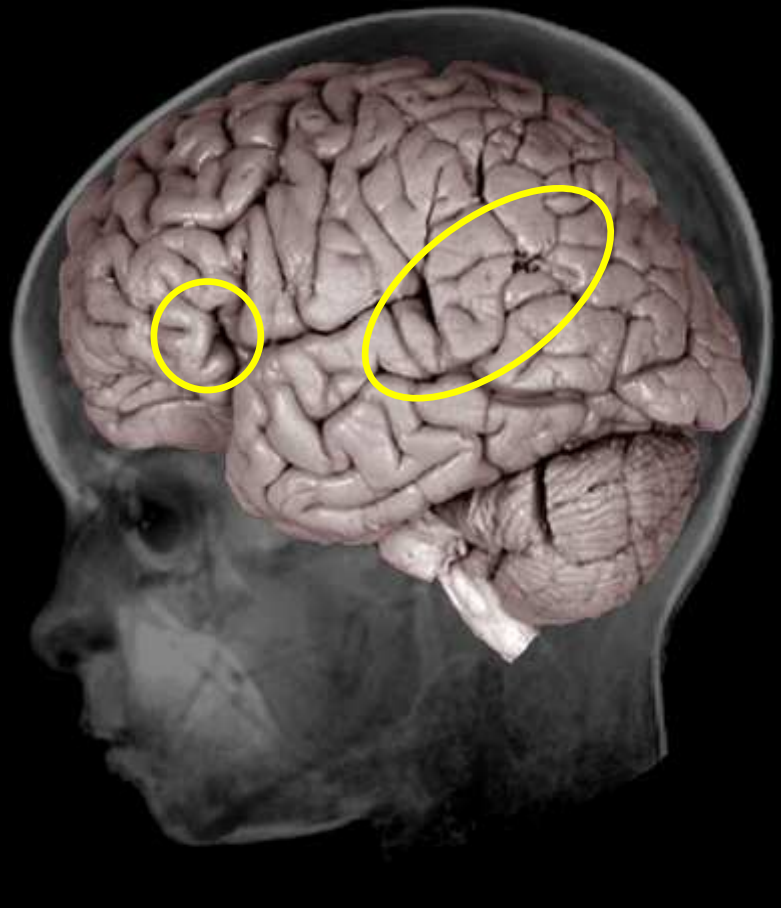
- 10-year-old boy
- Disordered
  - expressive/receptive language (first word at 3.5y)
  - social interaction
  - motor coordination
- Pervasive Developmental Disorder- Not Otherwise Specified
- Early intense interest in text
- Precocious reading

Ethan's Reading Scores

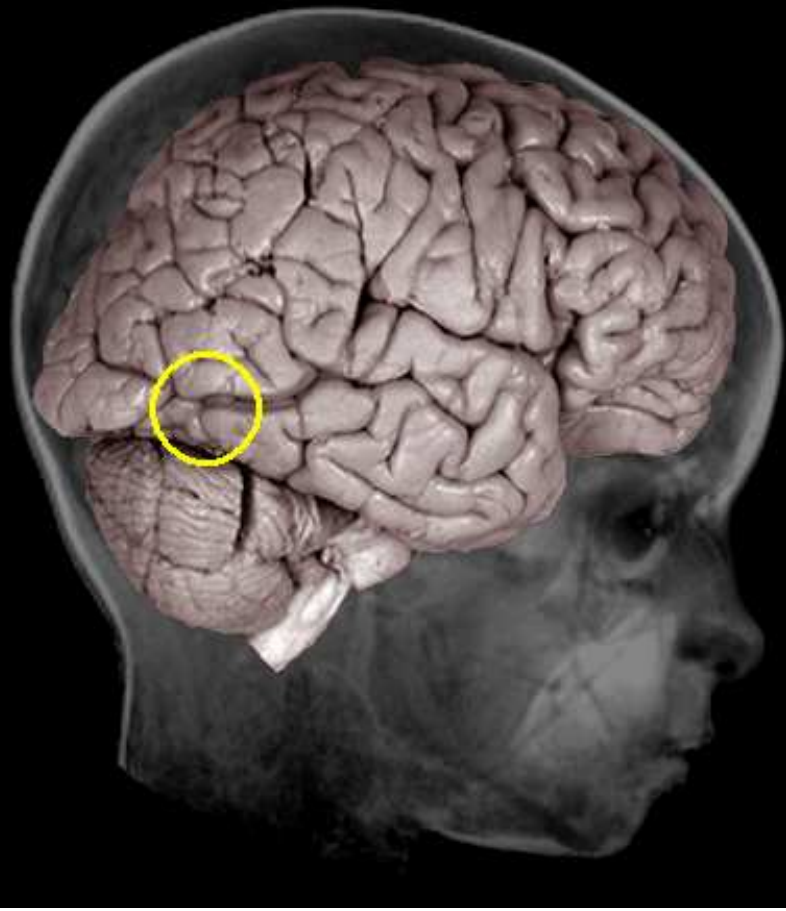
Age	Word I.D. Age eq.	Word Attack Age eq.	GORT Passage Age eq.	GORT Comp. Age eq.
5y-11m	8y-10m	9y-4m	10.3	<7.9
9y-9m	15y-1m	16y-11m	14.9	12.1

Hyperlexia Hypotheses

Left Hemisphere
Phonological Advantage
Welsh et al., 1987



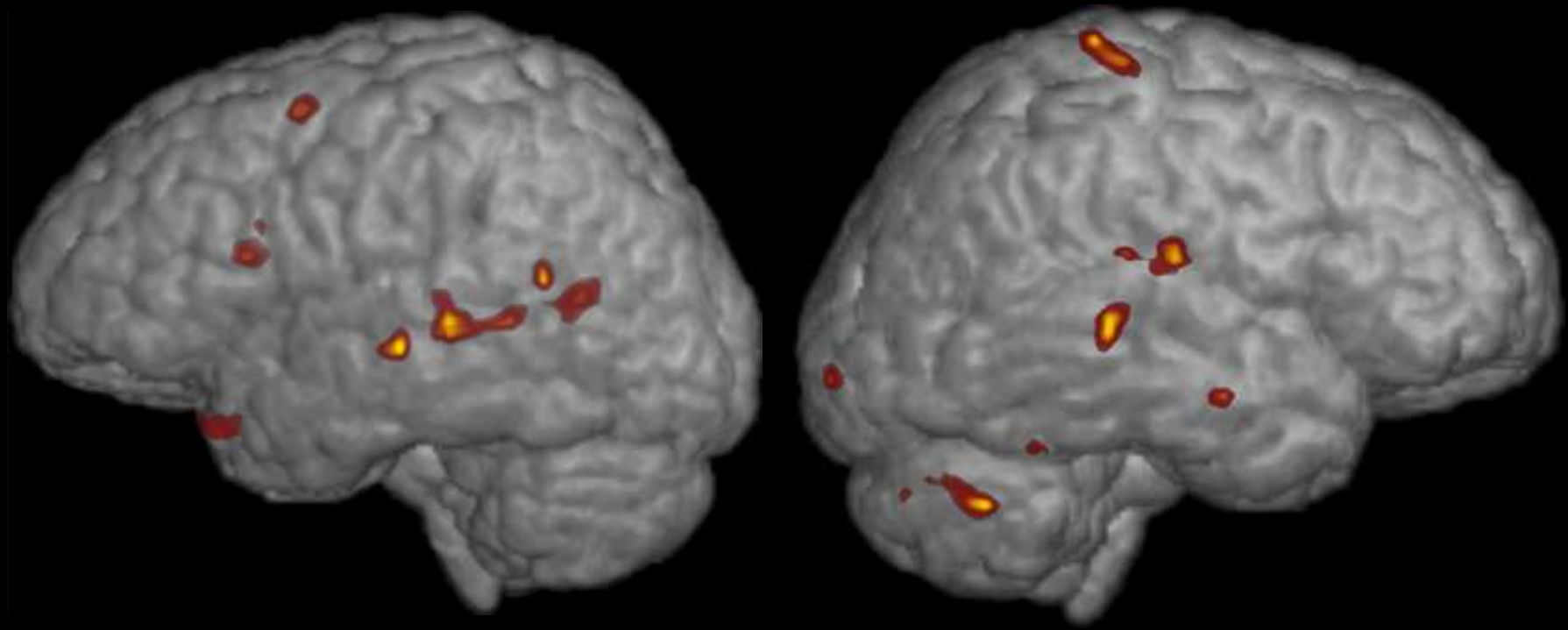
Right Hemisphere
Visual Advantage
Cobrinik, 1982



Methods

- Same fMRI methods as cross sectional study
- Compared Ethan to two control groups
  - Age Matched (n=9)
  - Reading Matched (n=8)

Ethan- Implicit Reading



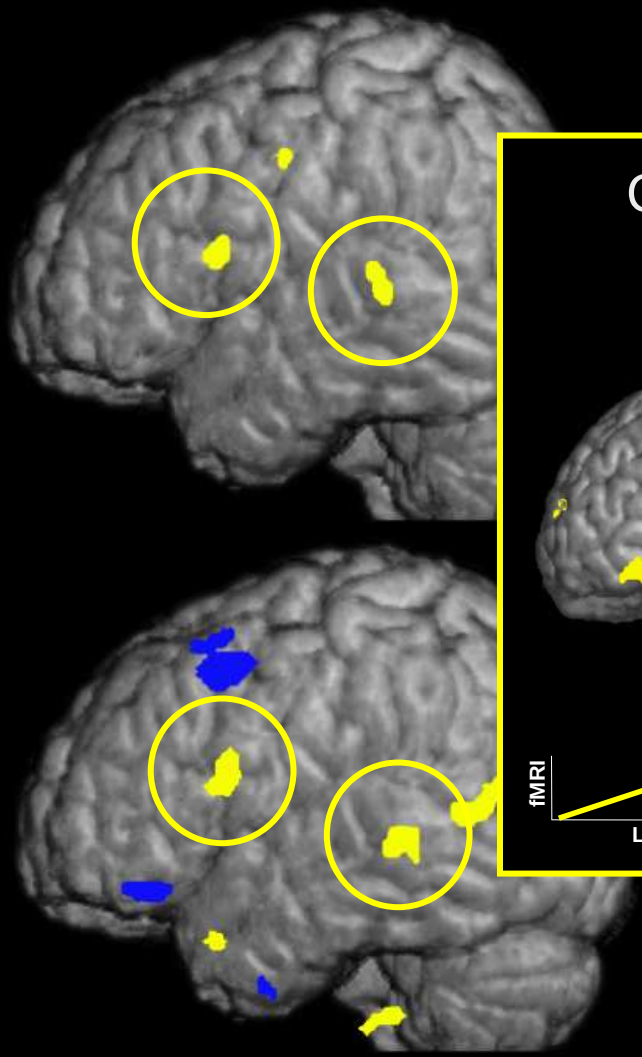
Turkeltaub et al., Neuron 2004

P< .005

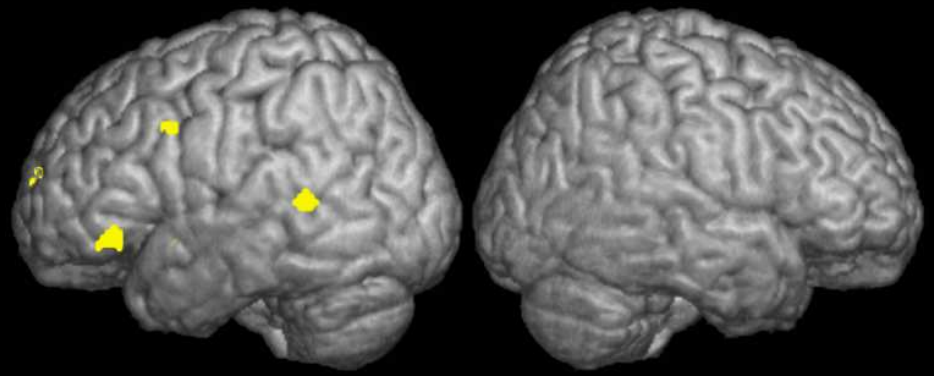
Ethan vs. Controls
Left Hemisphere

Age Matched (n=9)

Reading Matched (n=8)



Correlations with Phonological Awareness



p< .005, peak p< .0005

Ethan vs. Controls
Right Hemisphere

Age Matched (n=9)

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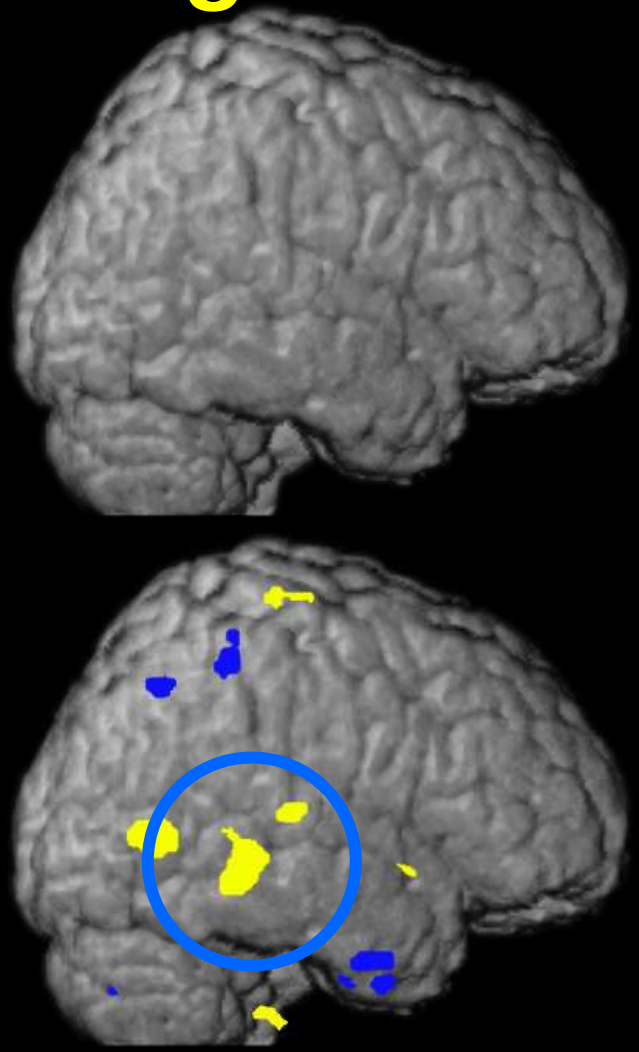
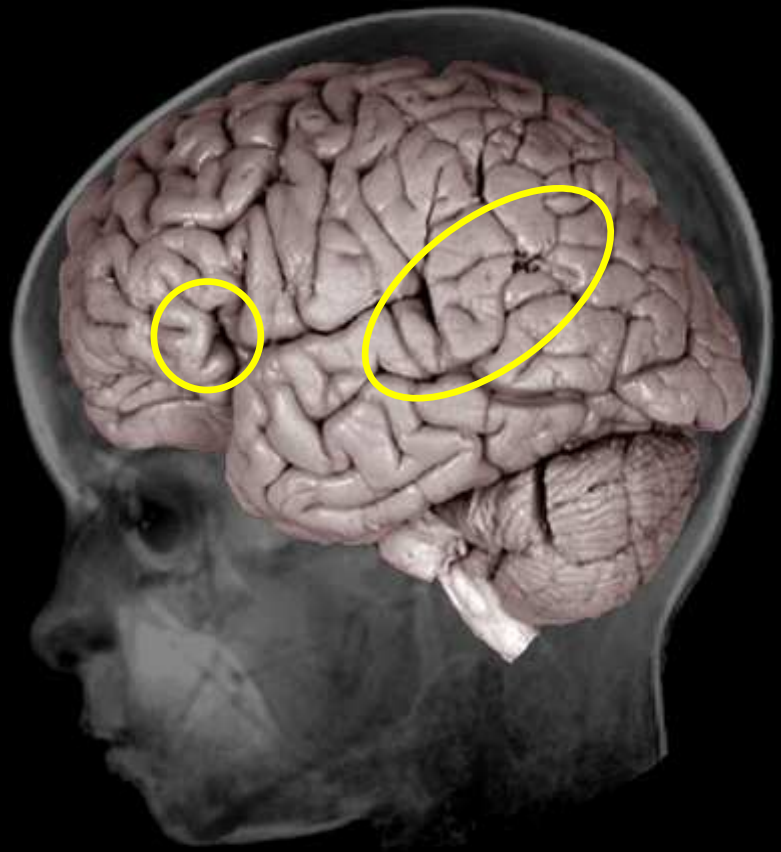


Reading Acquisition

Hyperlexia Hypotheses

Left Hemisphere
Phonological Advantage
Welsh et al., 1987



Right Hemisphere
Visual Advantage
Cobrinik, 1982

Conclusions

- In contrast to single hemisphere theories, Ethan demonstrated both
  - Hyper-activity in left hemisphere phonological areas
  - Increased activity in right hemisphere visual areas
- Left temporoparietal cortex is hyper-active in hyperlexia


Newsweek
Dyslexia
New Hope For Kids Who Can't Read
TIME
Overcoming Dyslexia
b d

The International Dyslexia Association / NICHD Research Definition of Dyslexia

- a specific learning disability, neurological in origin

- characterized by difficulties with accurate/ fluent word recognition, spelling and decoding abilities and the phonological components of language

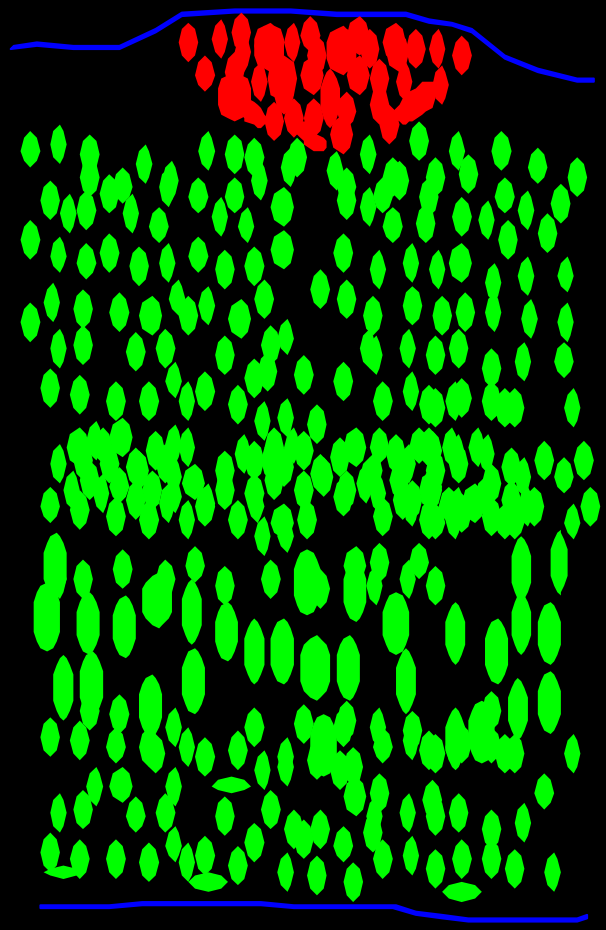
- unexpected in relation to other cognitive abilities and the provision of effective instructions

How Do You Know It's Dyslexia?

Measurement:

- Single Word Reading
- Phonemic Awareness
- Automatic Naming Speed
- Verbal Working Memory

Malformations



I

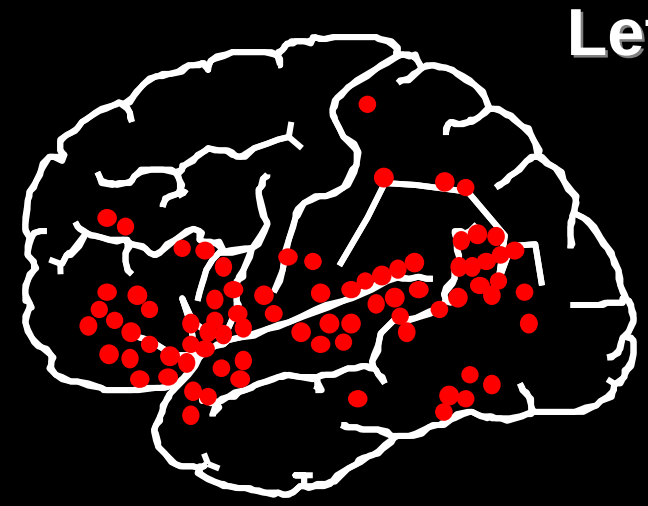
II

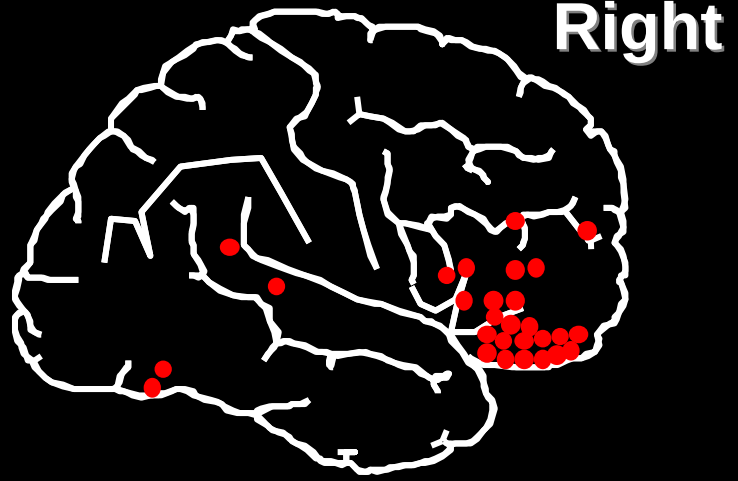
III

IV

V

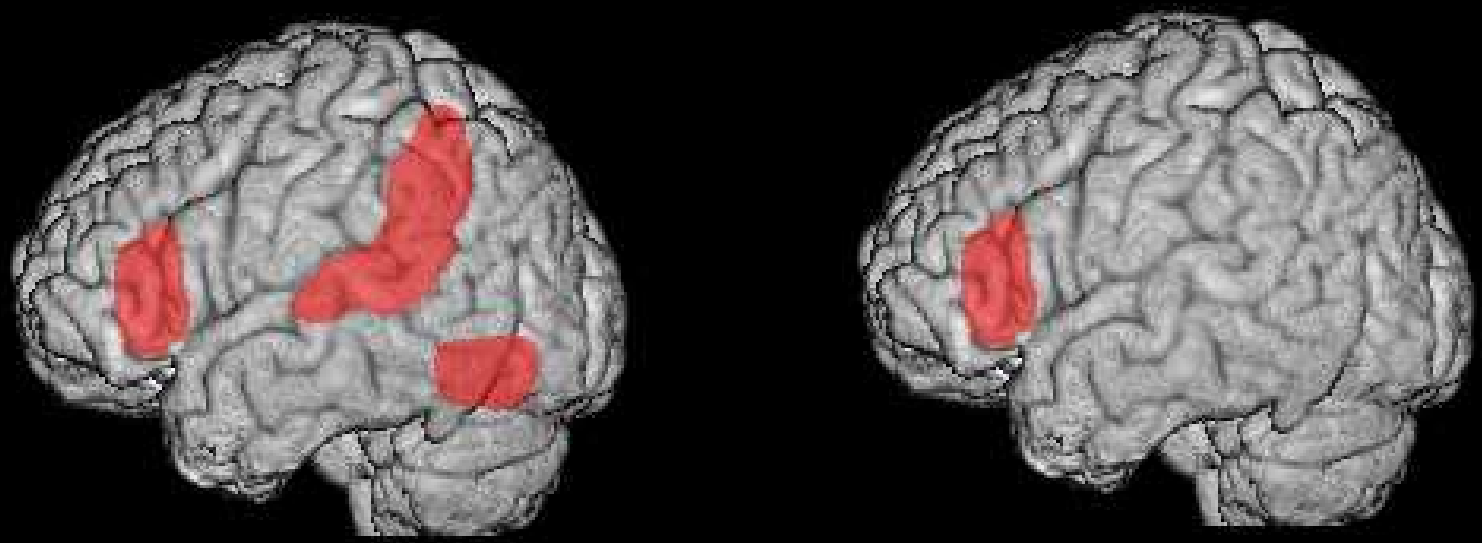
VI





Galaburda et al. 1985

Neurobiological Basis of Dyslexia



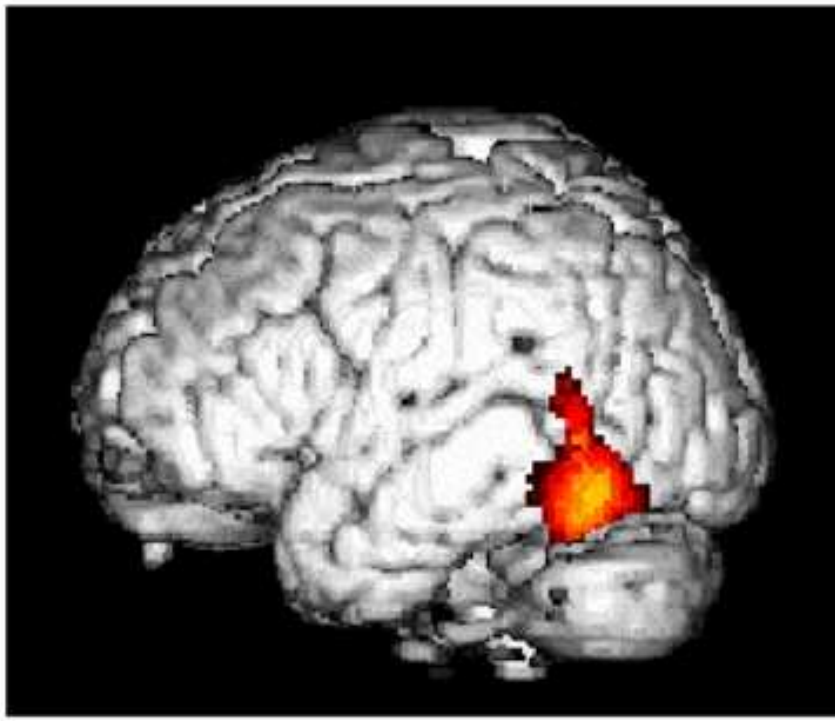
Typical Readers

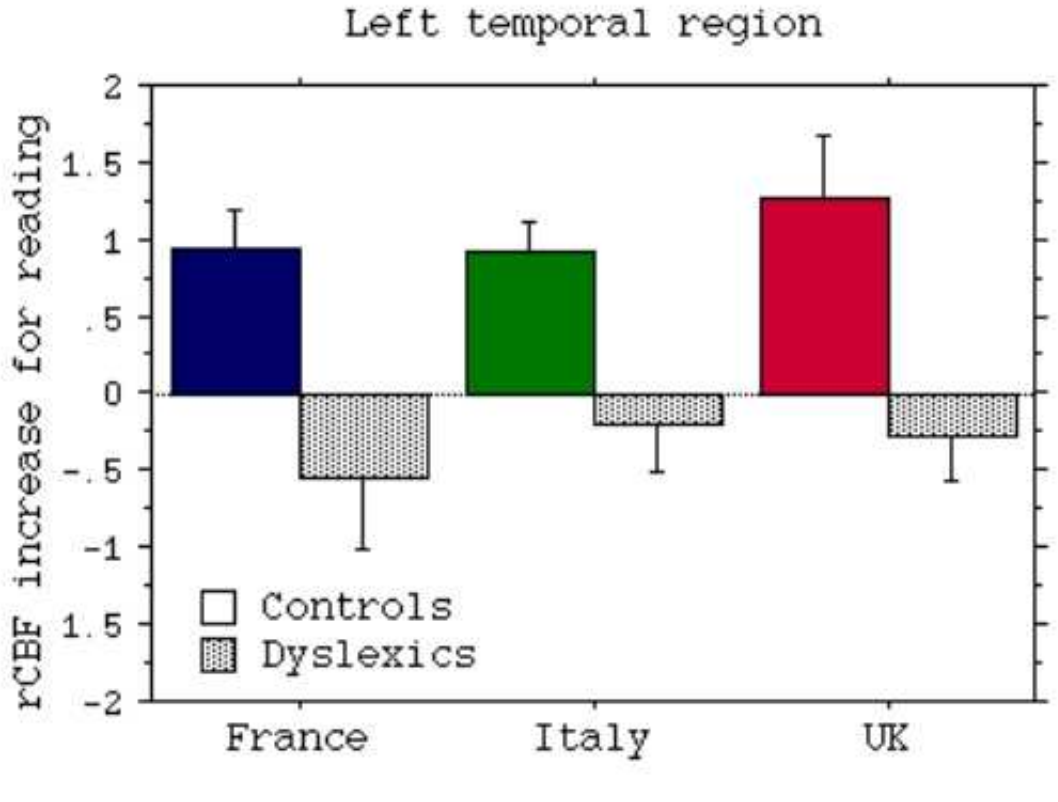
Dyslexic Readers

Dyslexia across cultures: same or different?

Same brain region less active in dyslexics during reading tasks in all countries

Controls > Dyslexics





Paulesu et al., 2001

Phonemic Awareness

- Awareness that language is composed of small sounds
- Hearing how sounds and sound patterns work in our language system

Phonemic Awareness

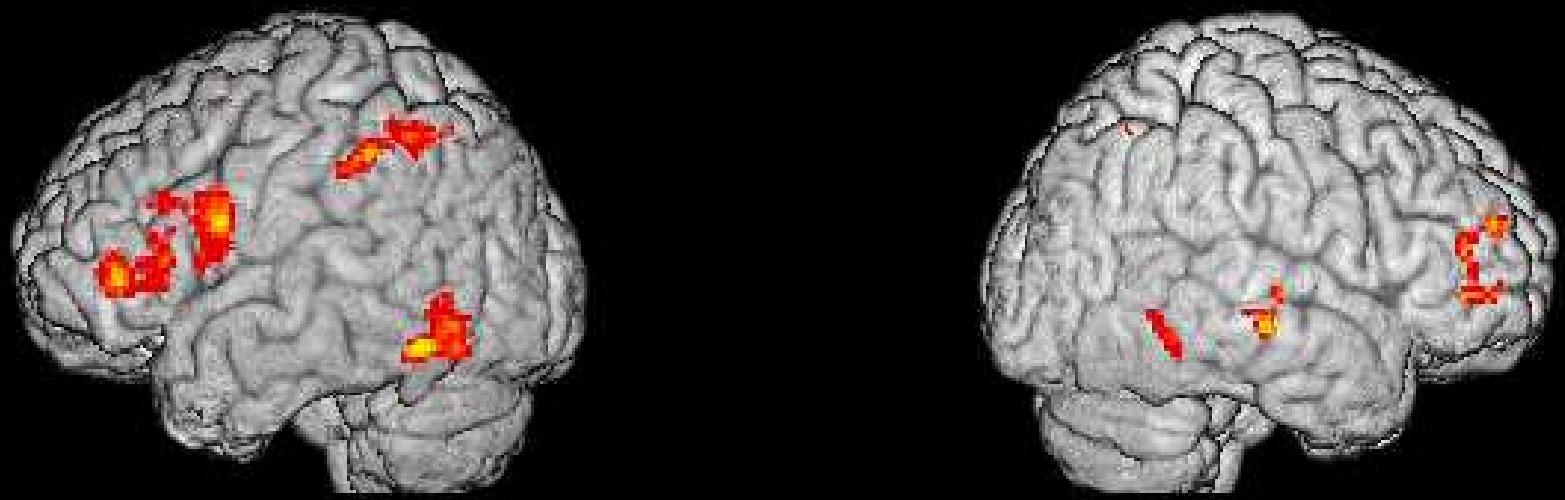
Measurement with deletion tasks:

- Say cowboy without saying boy = “cow”
- Say pink without the /p/ = “ink”
- Say robe without the /b/ = “row”
- Say blend without the /l/ = “bend”

Phoneme Deletion

Task	fixate	repeat	delete
Stimulus	+	rat	rat
Response		rat	at
Processes	fixation	vocalization	vocalization + phonological manipulation

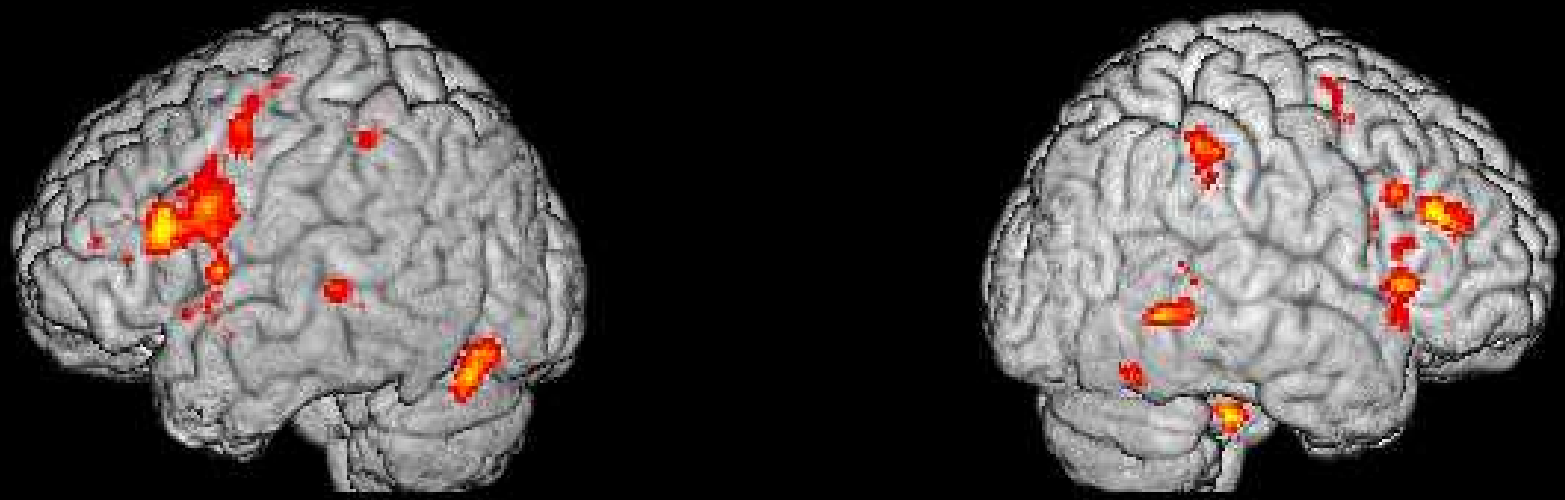
Typical Readers:
Deletion versus Repetition



left

right

Dyslexic Readers:
Deletion versus Repetition



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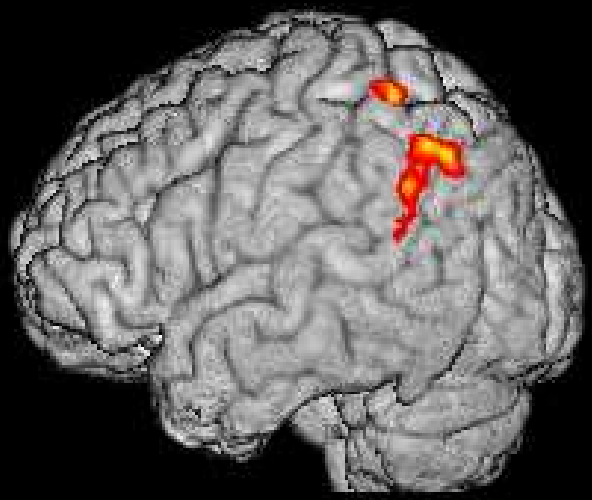
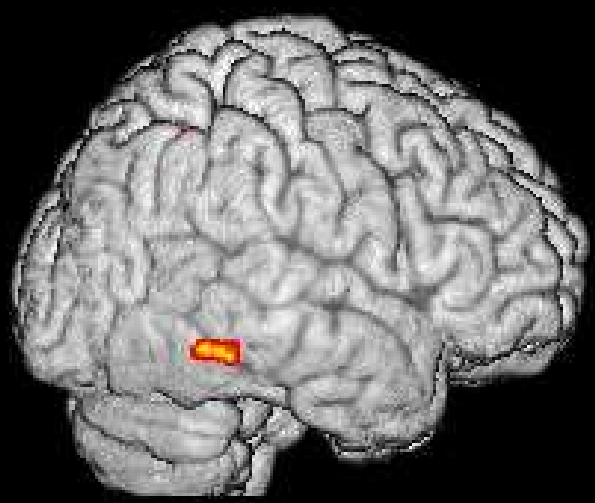
Group Comparison:
Controls > Dyslexics





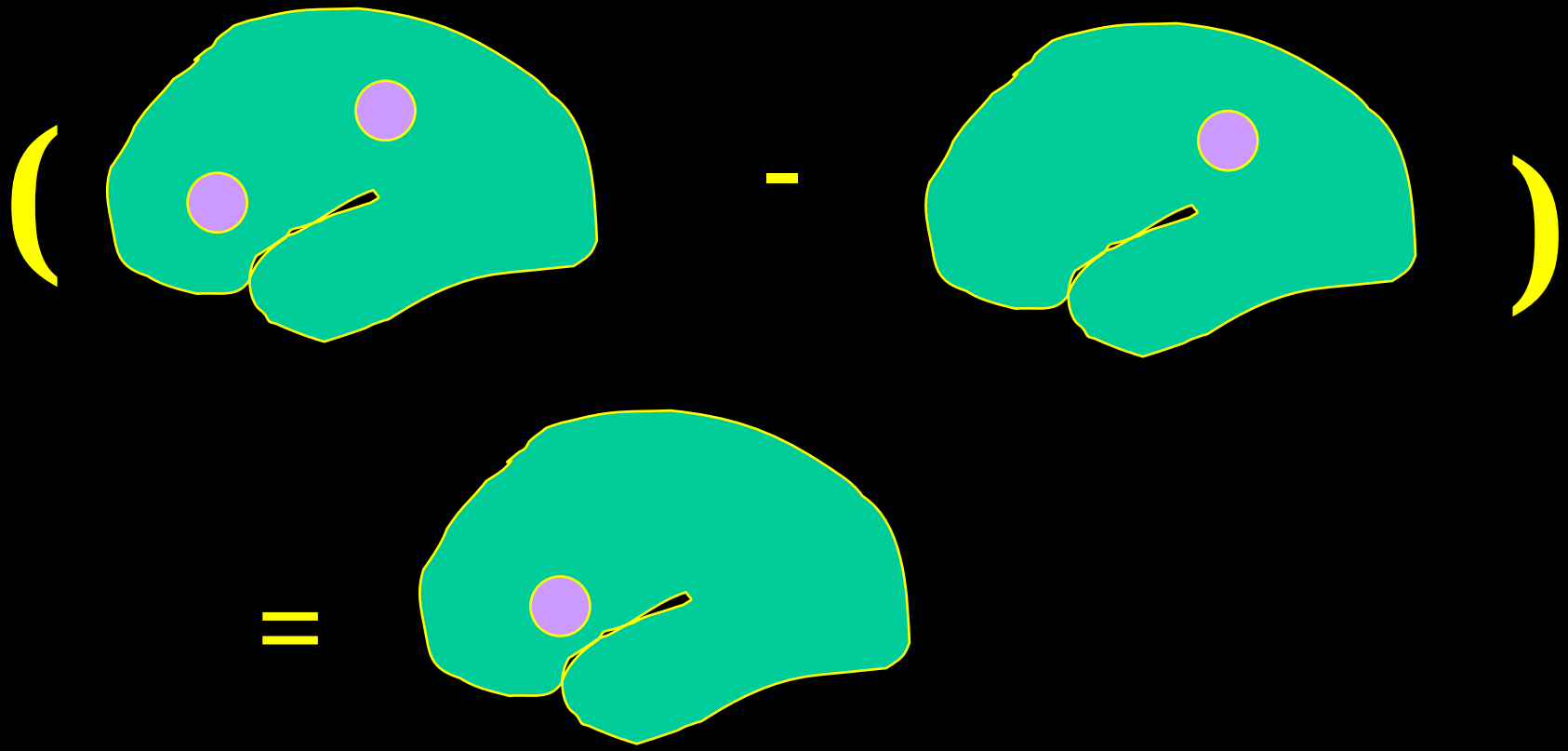
left

right

Eden et al., Neuron 2004

After Intervention

Before Intervention

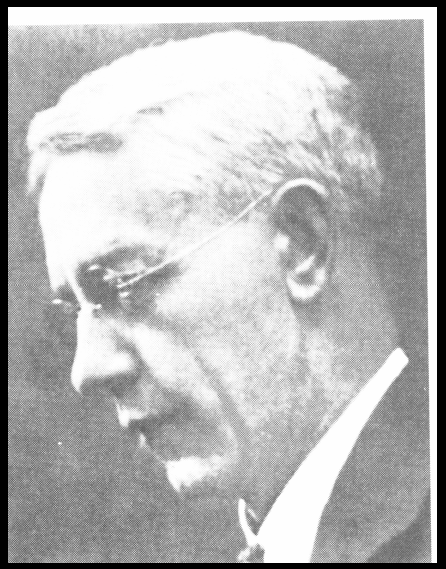


Study Design

- Assignment of individuals into different interventions
- Groups are equal in reading measures prior to the intervention
- Compare the two groups after intervention

	Group1	Group 2
Pre intervention		
	A	B
Post intervention		

June and Samuel Orton



Adult Phonological Intervention Study

Subjects:

- 20 Adults from Orton Center, recruited through Wake Forest University

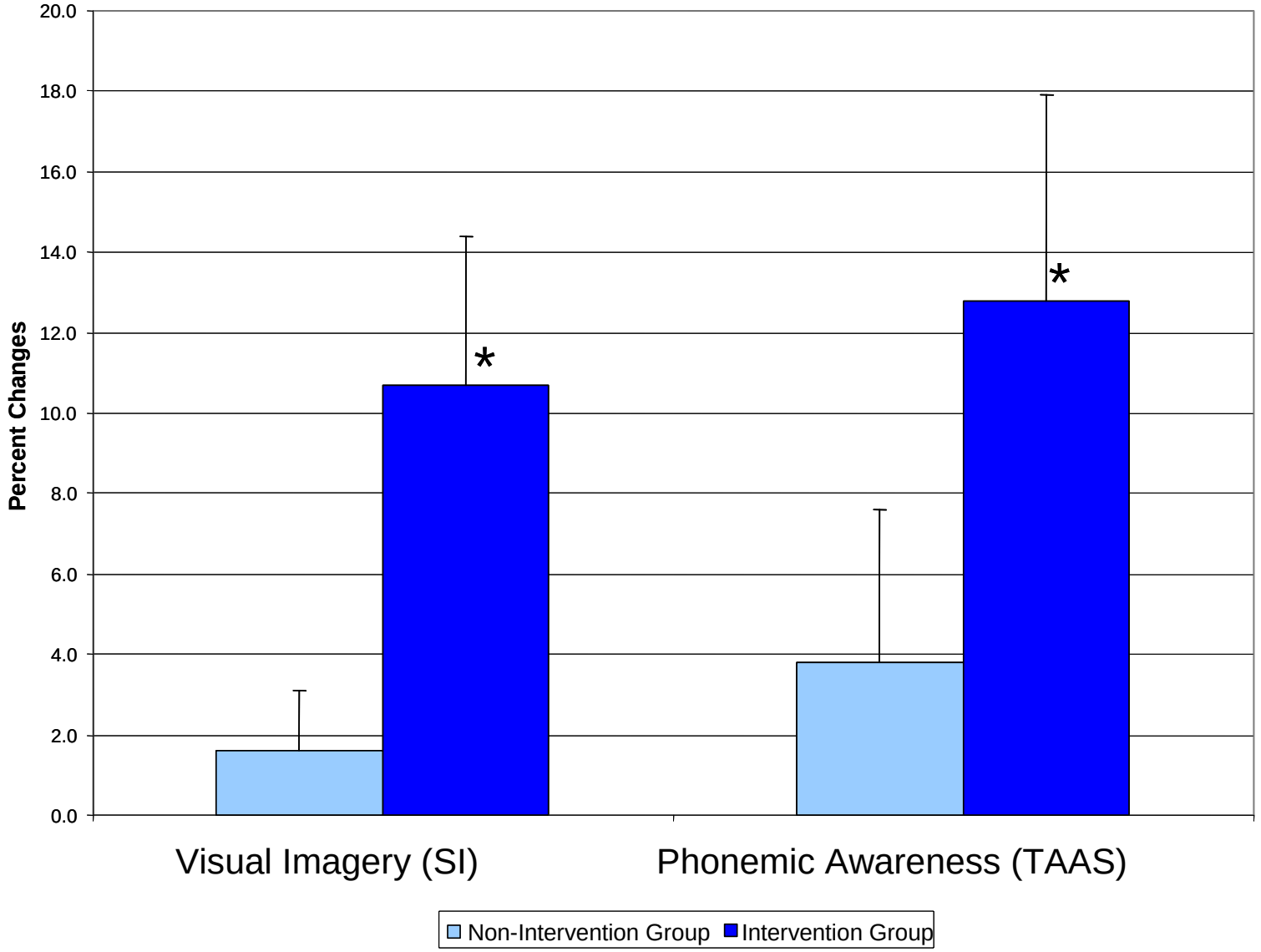
Intervention:

- 112.5 hours of Lindamood-Bell (over 8 weeks)

Before and after measures:

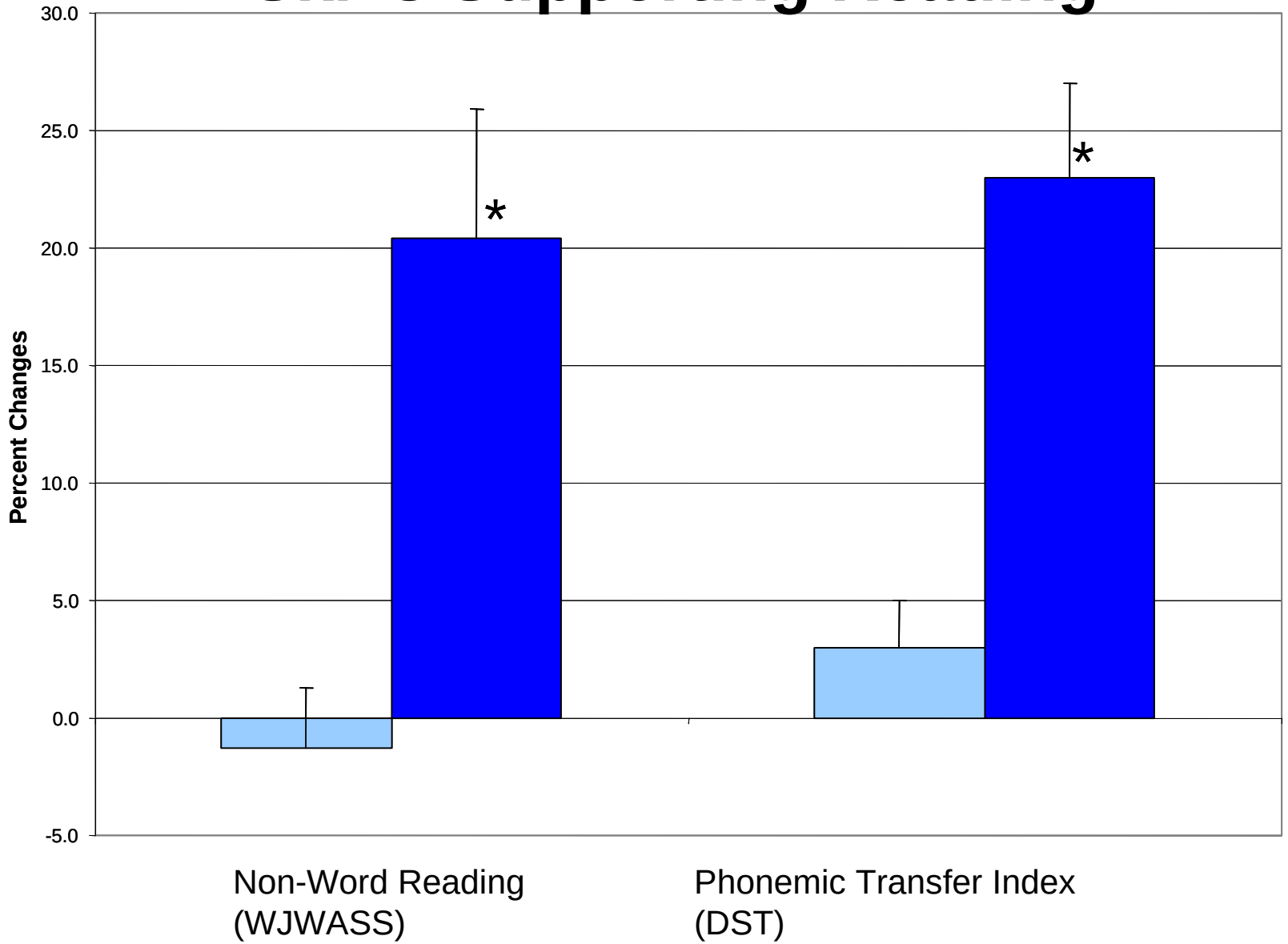
- Behavior: reading, phonological awareness
- Physiology (fMRI): phonemic segmentation

Skills Targeted by Intervention



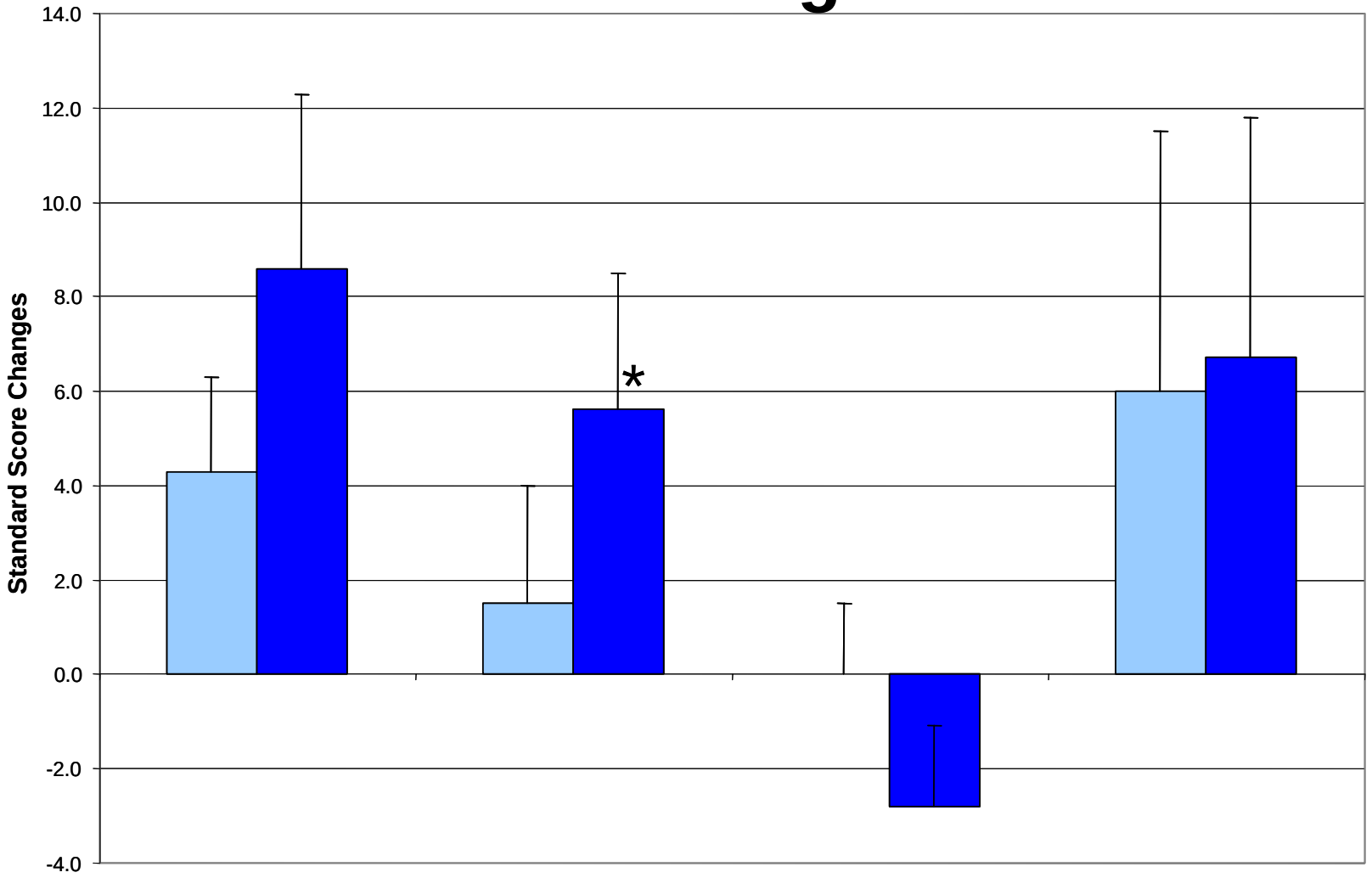
*p < .05

Skills Supporting Reading

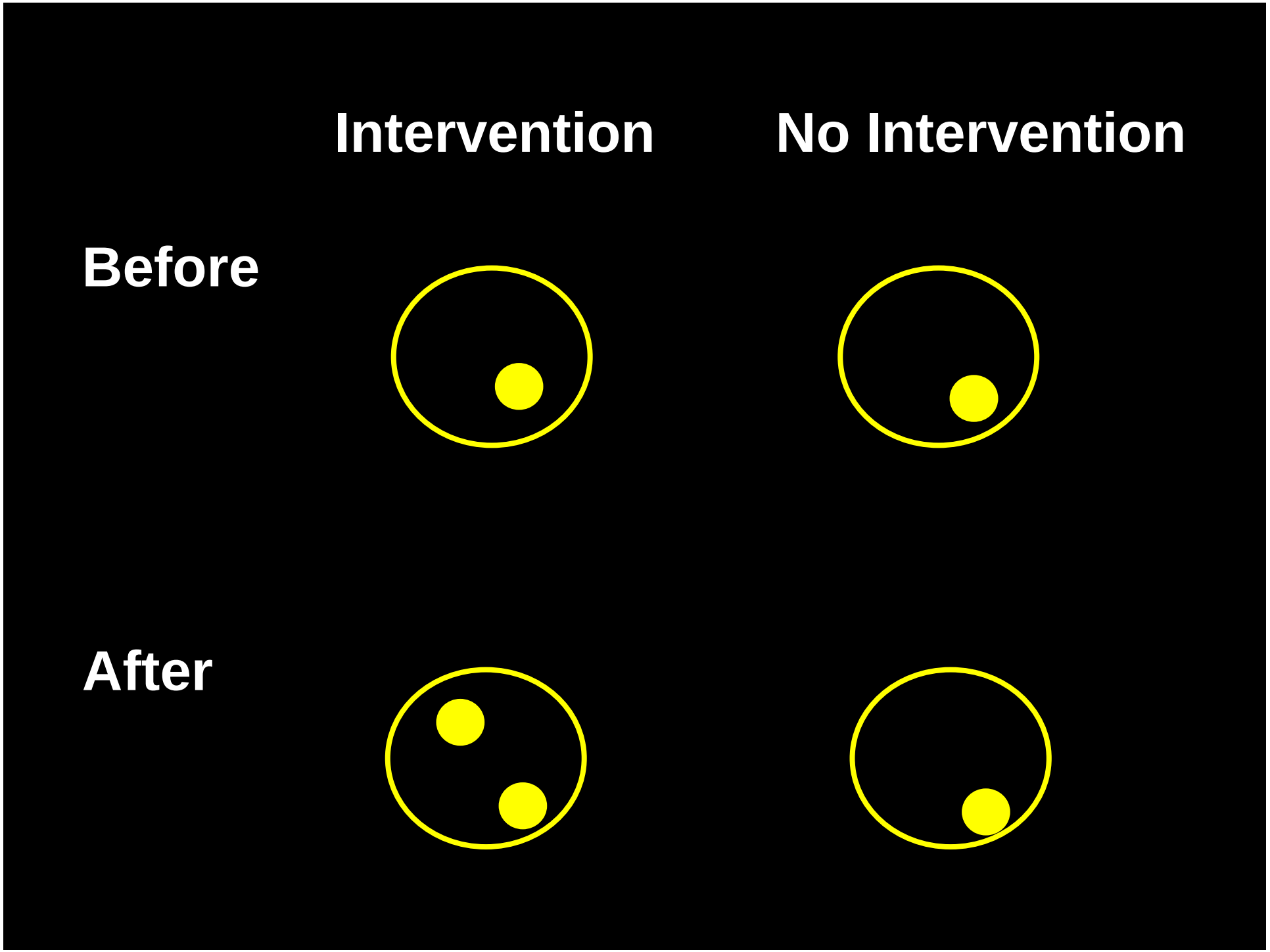


*p < .005

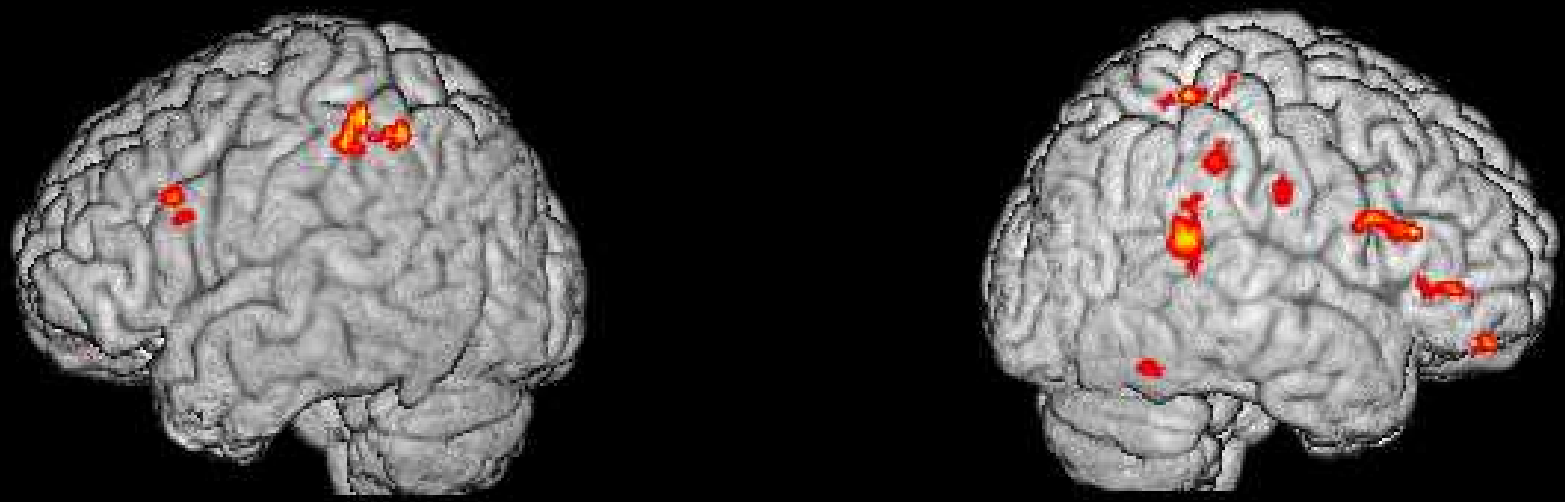
Oral Reading Skills



*p < .05


Intervention
No Intervention
Before
After

ANOVA Group x Day:
Increases in Activity Following Intervention



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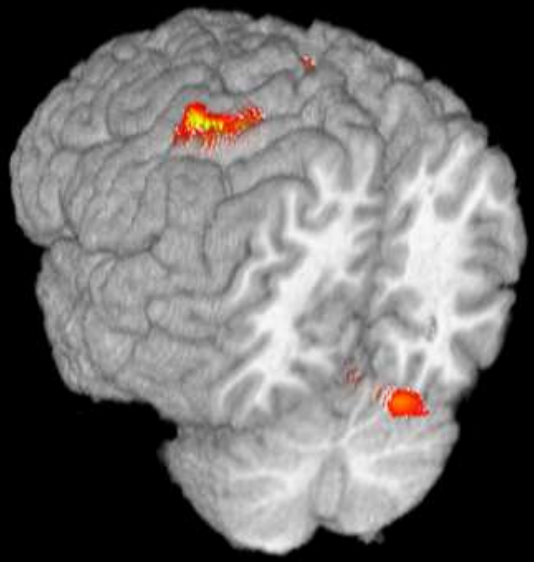
Eden et al., Neuron 2004

Conclusion



- After phonological intervention adults with dyslexia show increased activation in the left and right hemispheres.
- The right hemisphere areas are similar to those in the left hemisphere involved in phonological processing in good readers.

Overall Summary

- Regions know to be involved in the processing of information from multiple sensory modalities are also involved in PA.
- The neurobiological representation of these regions is established early on.

Overall Summary

- Dyslexic individuals show anomalous activity in these regions, especially parietal cortex.
- This activity becomes established following intensive remediation.

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