



**USAID**  
FROM THE AMERICAN PEOPLE

# Brain Imaging Studies of Reading

Guinevere Eden

Center for the Study of Learning



2015 Global Education Summit  
@USAIDEducation

#LetGirlsLearn

#endpoverty

# *Reading is a Cultural Invention*



**Divination Characters on Oracle Bones  
Shang Dynasty 1400-1100 BC**



**First use of alphabet  
1800 BC**

# *Magnetic Resonance Imaging (MRI)*



# Magnetic Resonance Imaging (MRI)

**MRI** studies brain anatomy.



**Functional** MRI (fMRI) studies brain function.

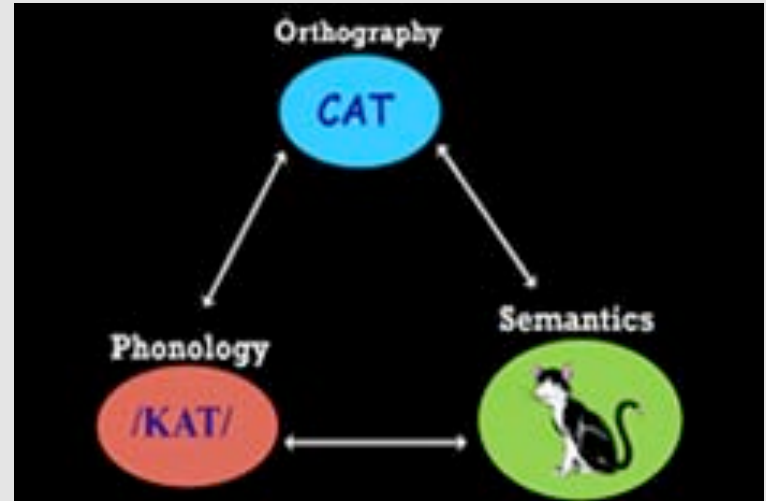


# *Reading Involves Mapping:*

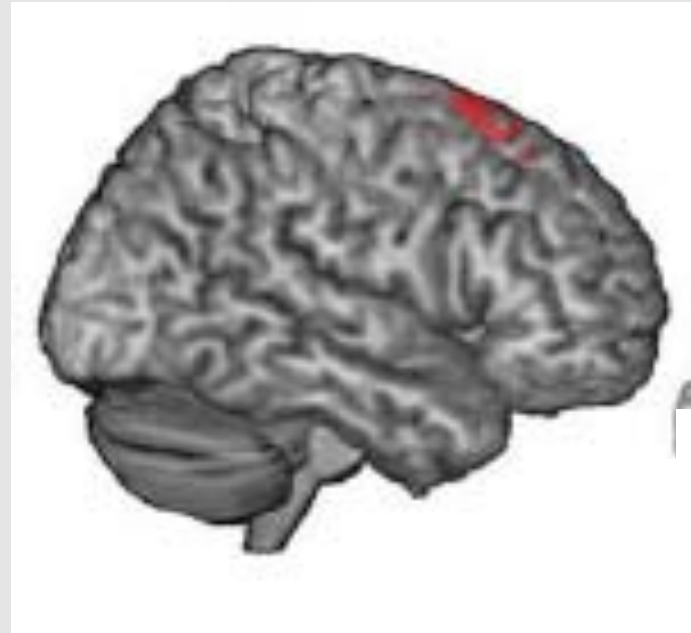
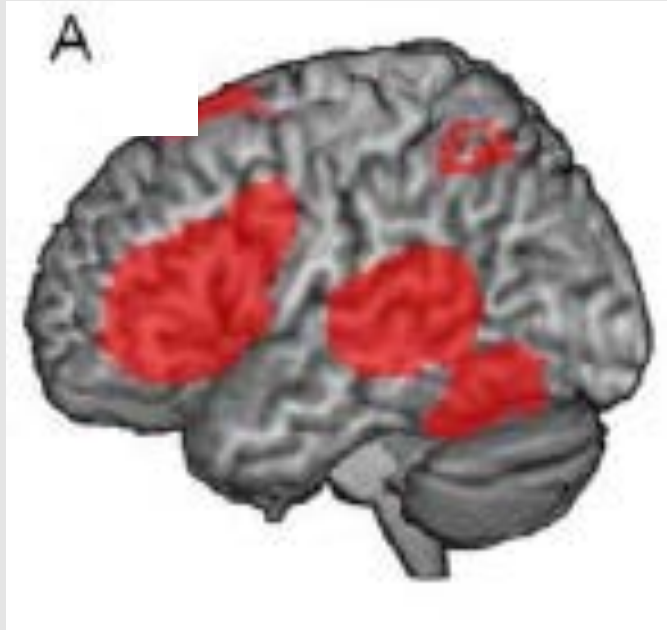
spelling patterns/word form (orthography)

sounds of words (phonology)

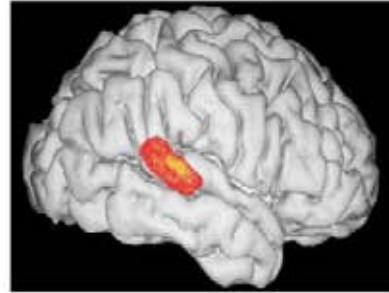
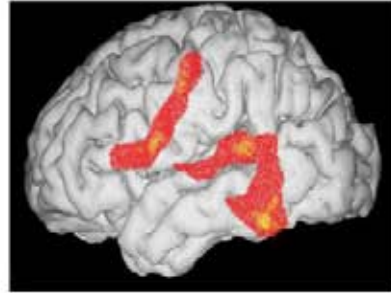
meaning (semantics)



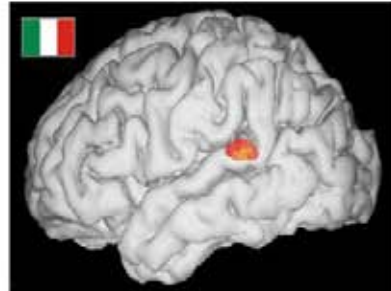
# *Brain Activity During Reading: Adults*



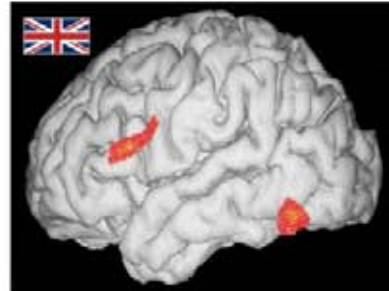
# Brain Activity During Reading: Different Languages



Network common to reading in Italian and in English

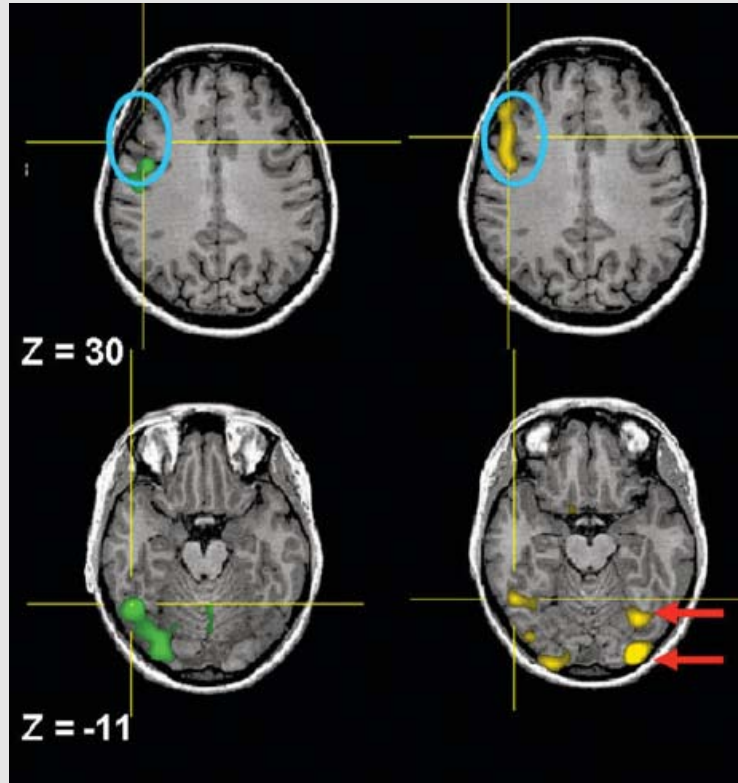


Stronger activation  
in Italian



Stronger activation  
in English

# Brain Activity During Reading: Different Writing Systems



Alphabetic    Logographic

Bolger et al. (2005)



# *MRI in Children*



# *Reading Outcome Depends On:*



**Alphabetic Principle**  
**Phonological Awareness**  
**Background Knowledge**  
**Vocabulary**  
**Familiarity with Sentence Structure, etc.**

# *Reading Acquisition Rate Is Modulated By:*



**Language**

**Orthography**

**IQ**

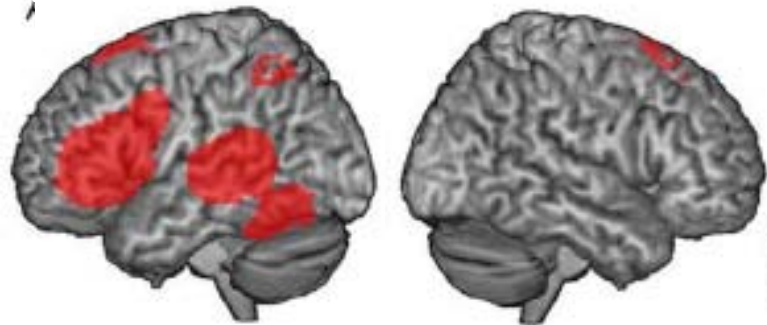
**Social Class**

**Gender**

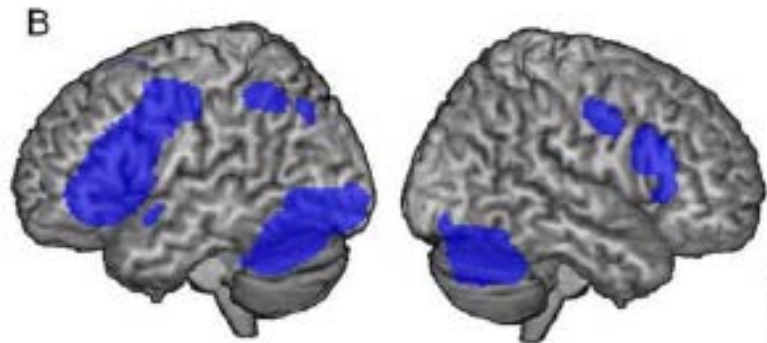
**Quality of Instruction**

# *Brain Activity During Reading: Meta-Analysis*

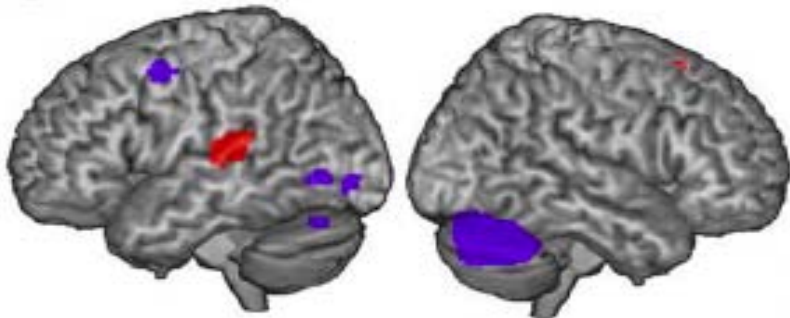
**Children**



**Adults**



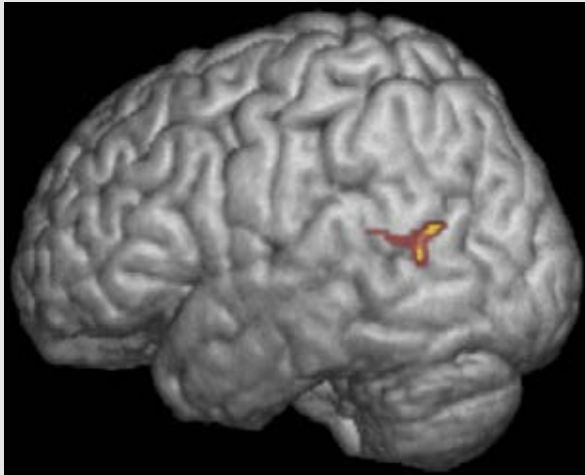
**Children versus Adults**



# *Brain Activity During Reading: Different Ages*

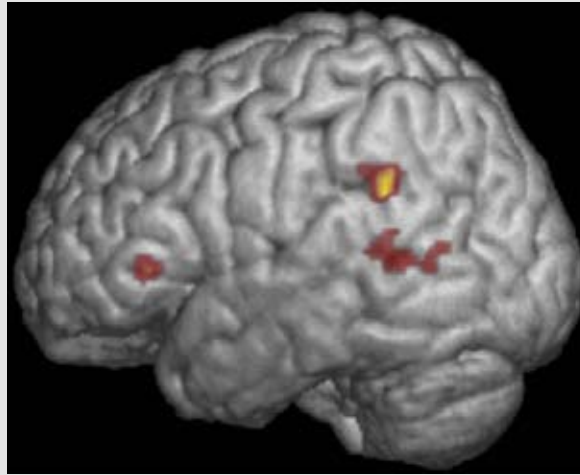
**6 – 9.4 y**

n=13



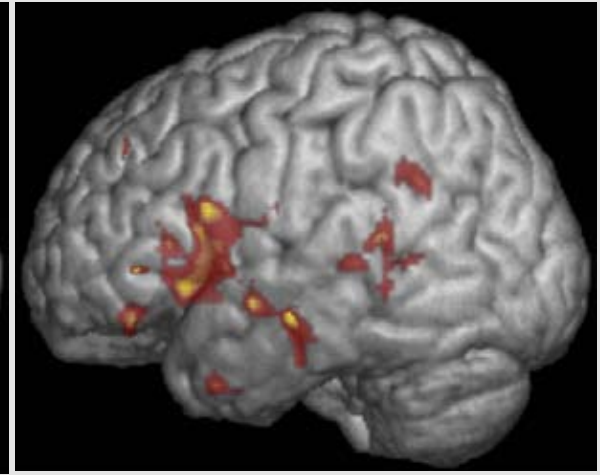
**9.4 – 18 y**

n=13

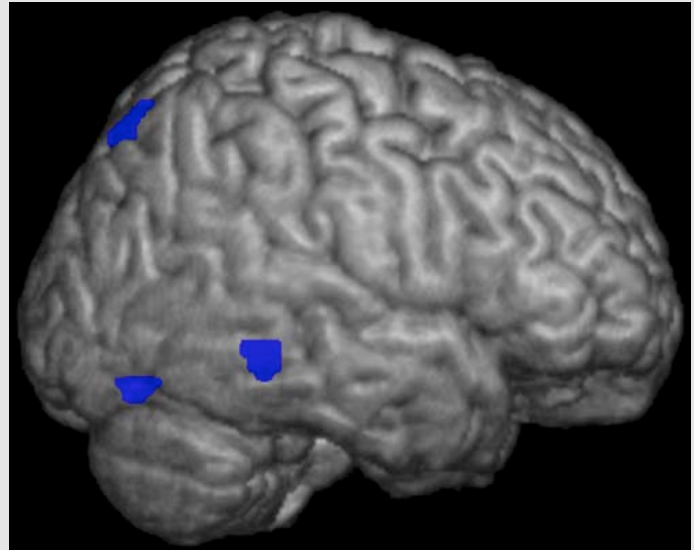
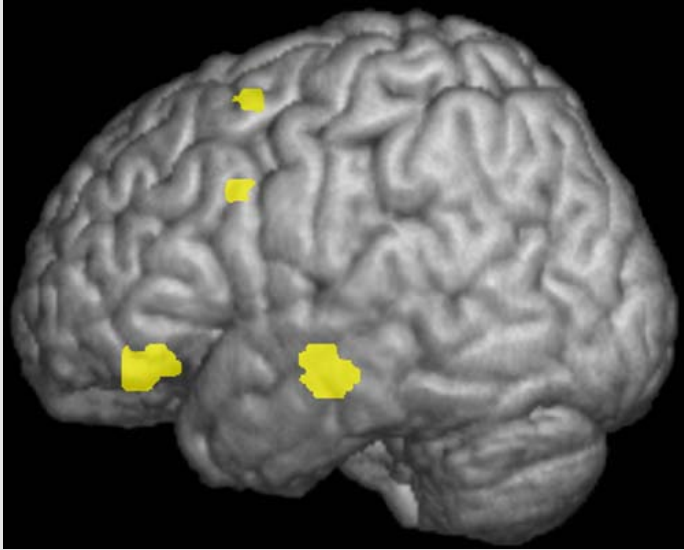


**20 – 23 y**

n=15



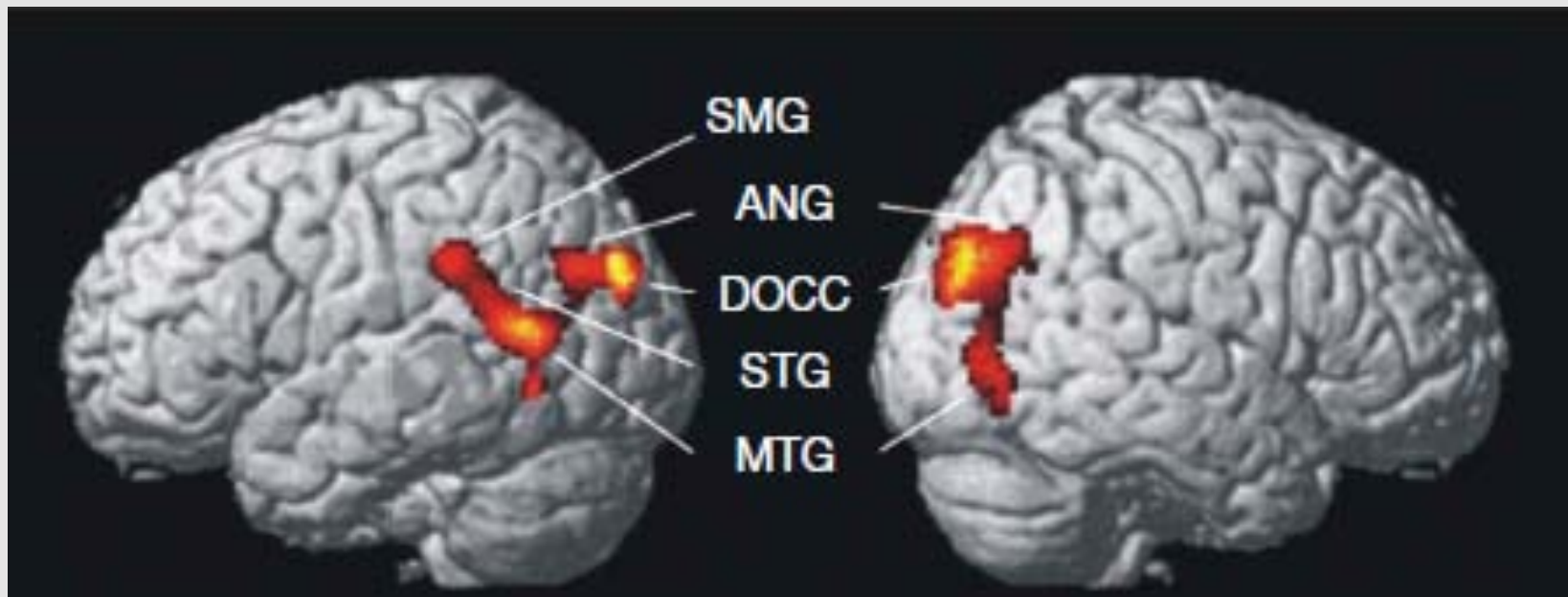
# Brain Activity During Reading: Correlated with Reading Performance



fMRI  
Reading Composite

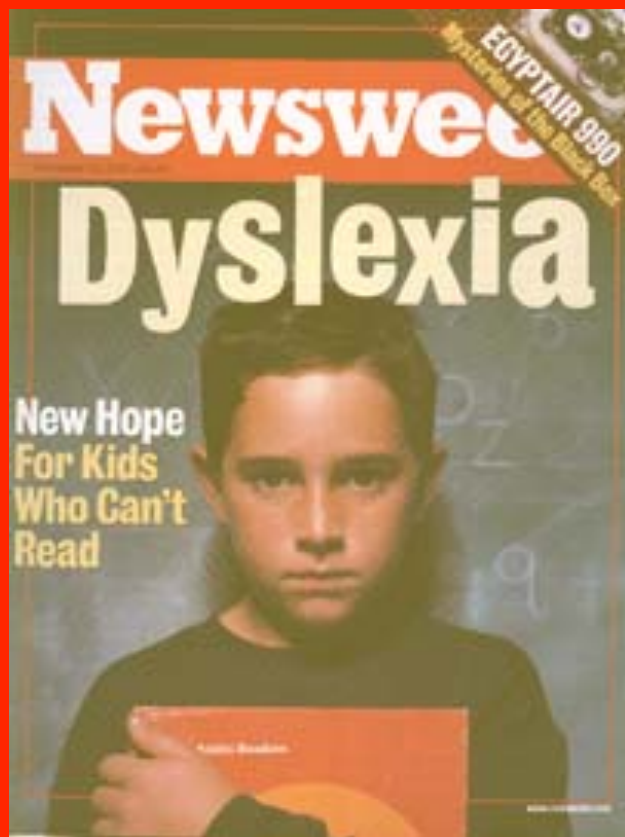
Turkeltaub et al., (2003)

# *Learning to Read Changes the Brain's Anatomy*



**More gray matter volume in literate compared to illiterate adults**

Carreiras et al. (2009)





# *International Dyslexia Association Research Definition of Dyslexia*

- Specific learning disability, neurological in origin
- Difficulties with accurate and/or fluent word recognition, poor spelling and decoding

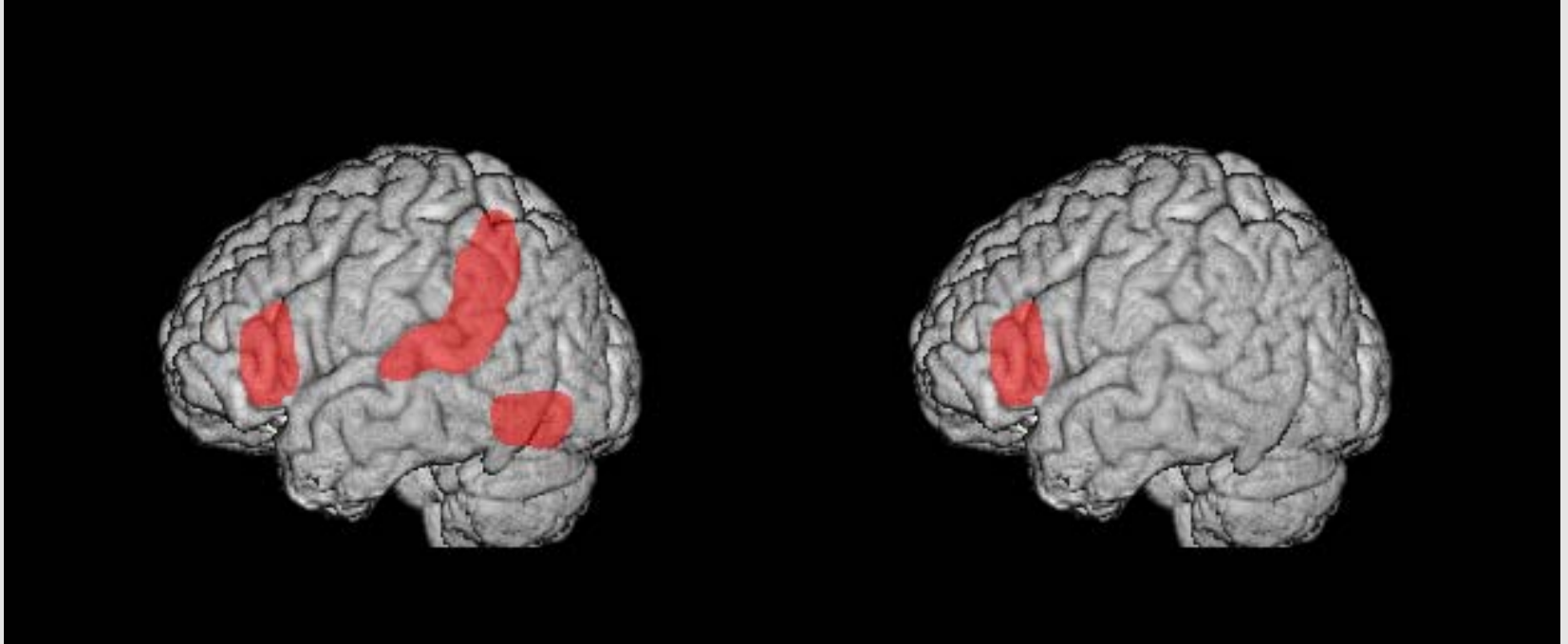
# *International Dyslexia Association Research Definition of Dyslexia*

- Unexpected in relation to other cognitive abilities and provision of instruction
- Secondary consequences include poor reading comprehension, growth of vocabulary and background knowledge

# *Developmental Dyslexia*

- Highly heritable: 40% chance if one parent has dyslexia (Olson et al., 1989)
- Prevalence: 7-12% of population (Katusik et al., 2001; Rutter et al., 2004)
- 2-3 times more prevalent in males vs. females (Rutter et al., 2004)

# *Functional Anatomy of Reading*



**Typical Readers**

**Readers with Dyslexia**

# Phoneme Deletion TASK

Task

fixate

repeat

delete

Stimulus

+

rat

rat

Response

rat

rat

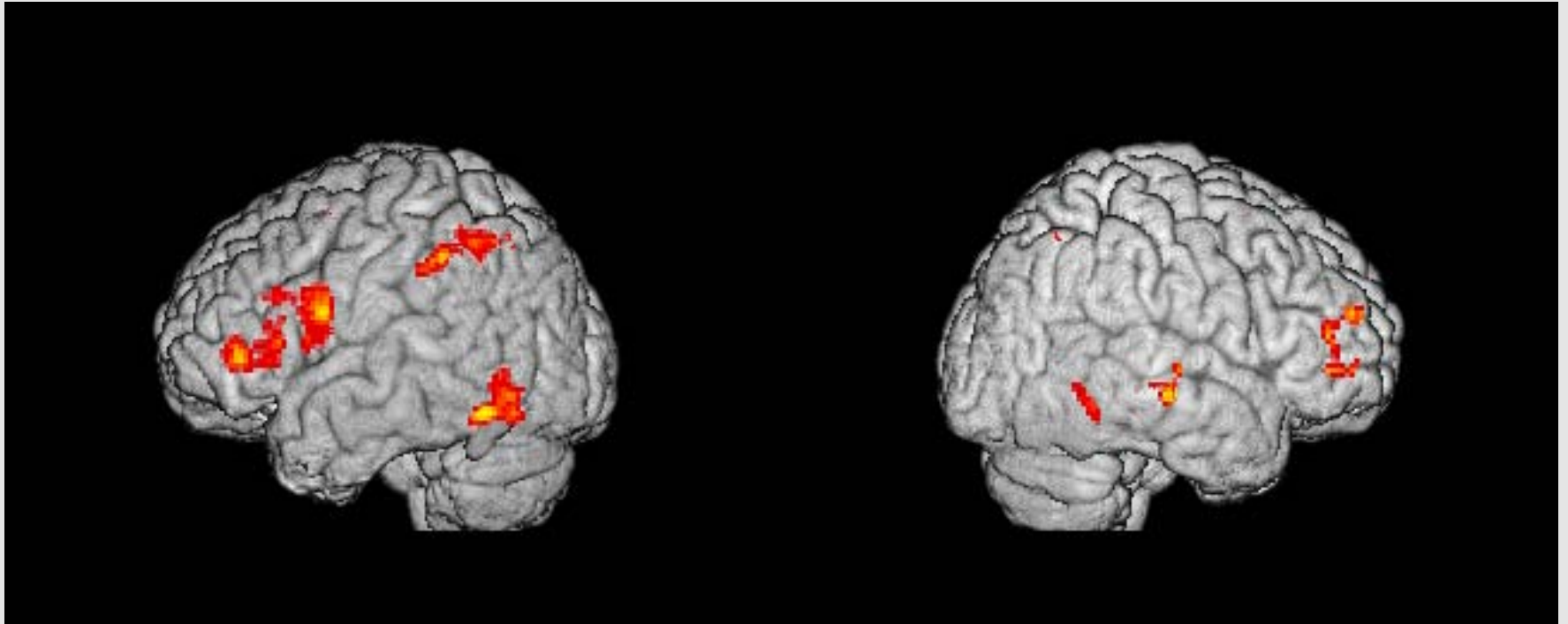
Processes

fixation

vocalization

vocalization  
+  
phonological  
manipulation

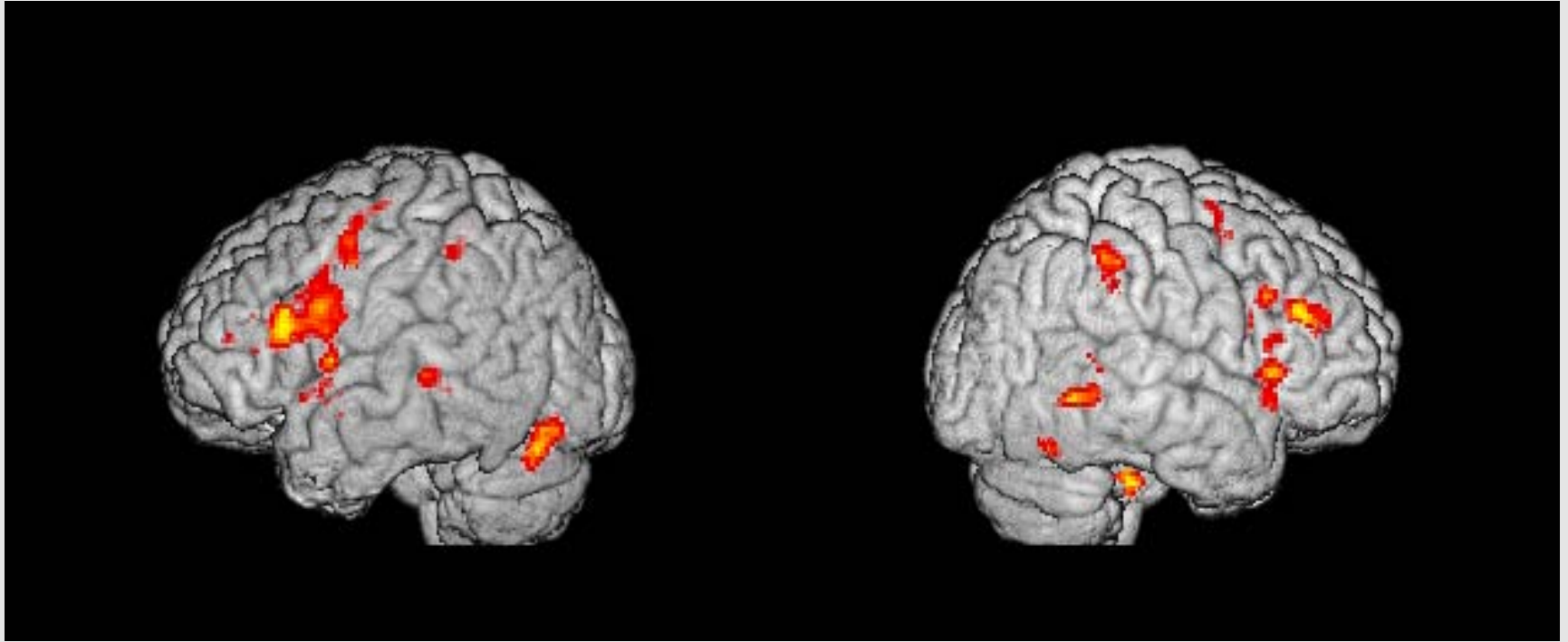
# *Typical Readers: Deletion versus Repetition*



left

right

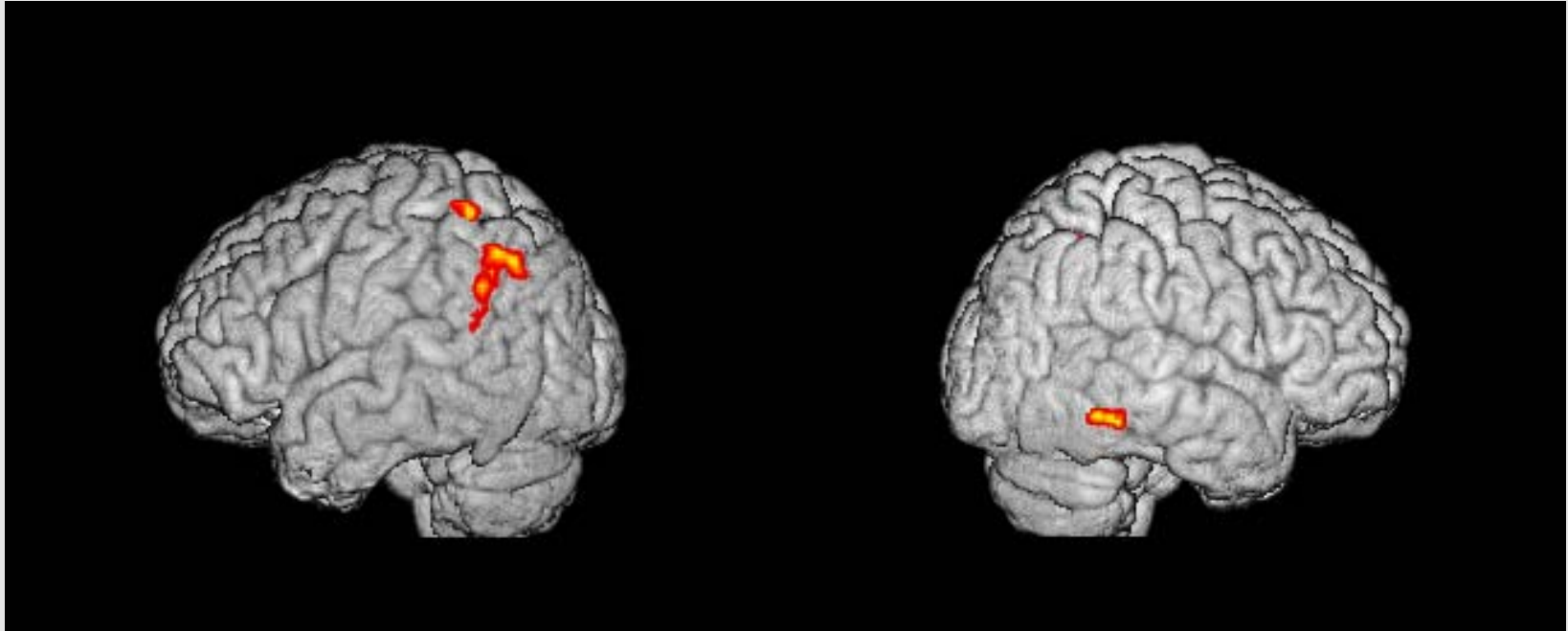
# *Readers with Dyslexia: Deletion versus Repetition*



left

right

# *Group Comparison: Controls > Dyslexics*



left

right



*After Intervention*



*Before Intervention*



-



=

*Growth in Total Reading Skill Before,  
During, and Following Intensive  
Intervention*

**Standard Score**

95  
90  
85  
80  
75

P-Pretest

Pre Post

1 year

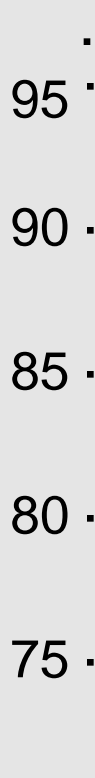
2 year

**Interval Between Measurements**

LIPS

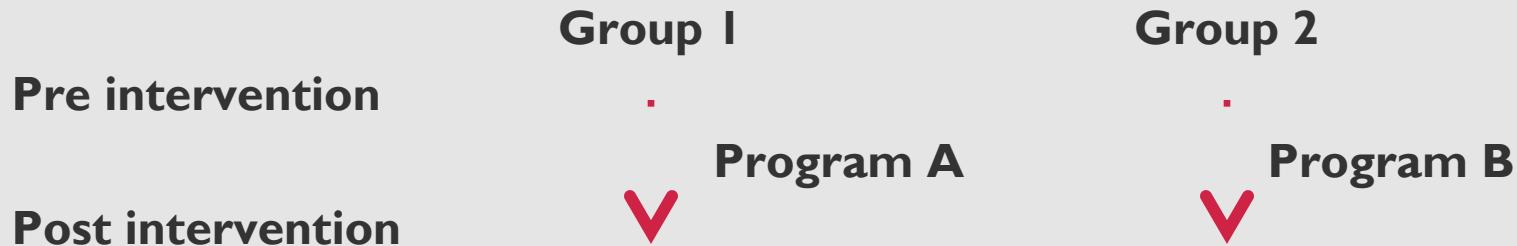
EP

Torgesen et al. (2001)

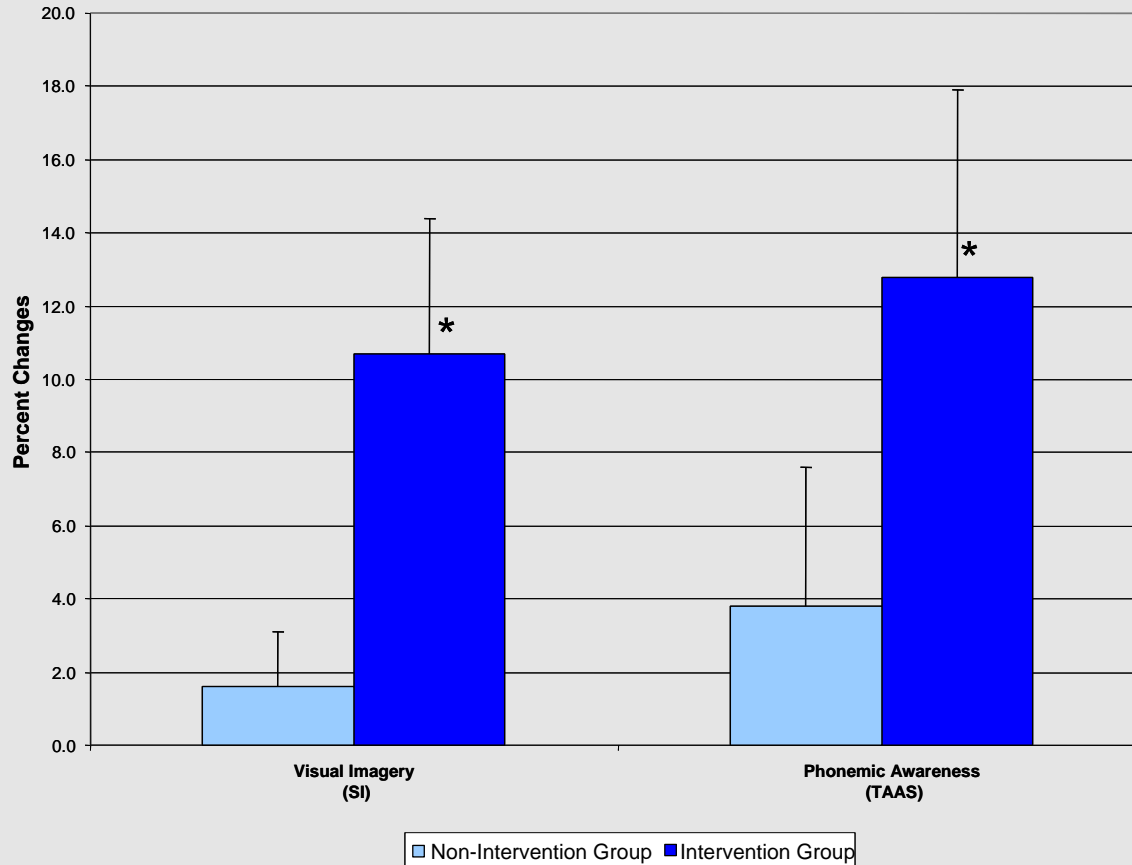


## *Intervention Trial: Study Design*

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

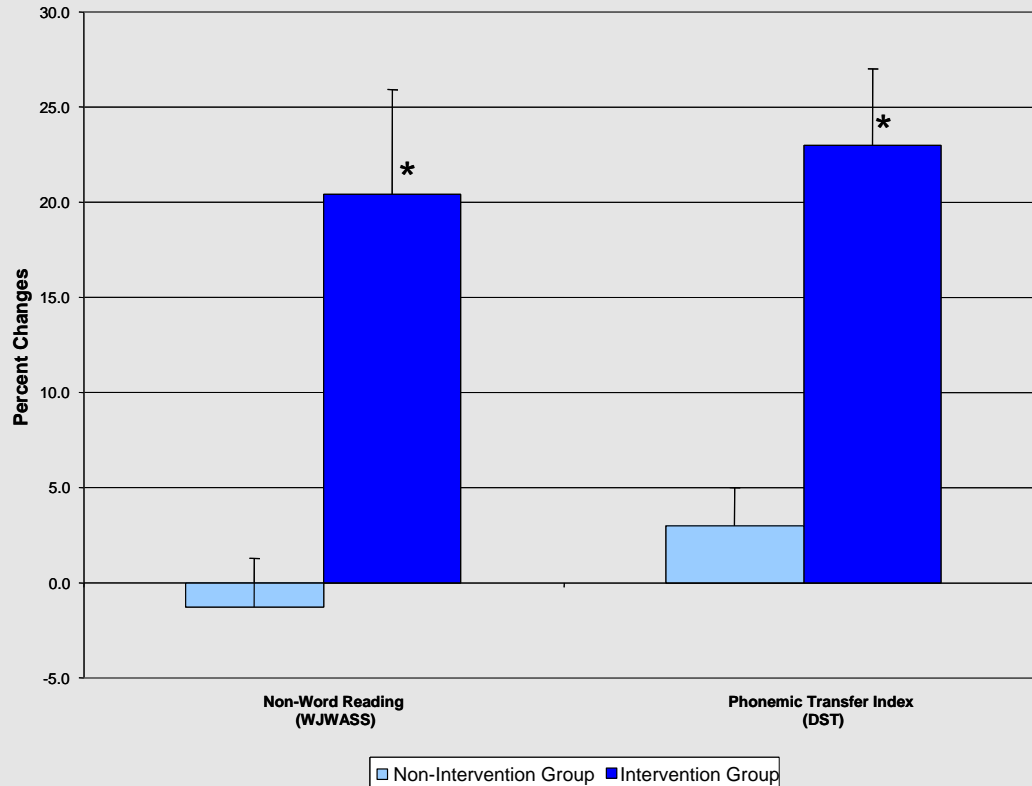


# Skills Targeted by Intervention



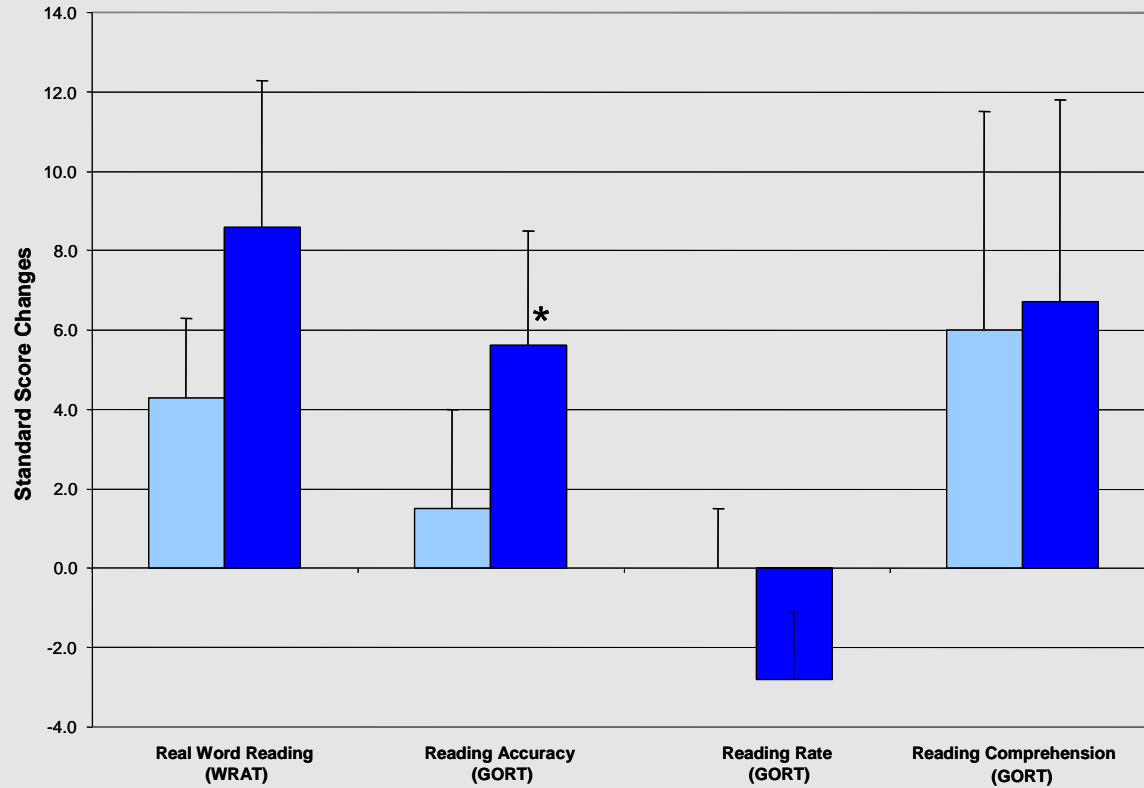
\*p < .05

# Skills Supporting Reading



\*p < .005

# Oral Reading Skills



\*p < .05

□ Non-Intervention Group   ■ Intervention Group

*Intervention*

*No Intervention*

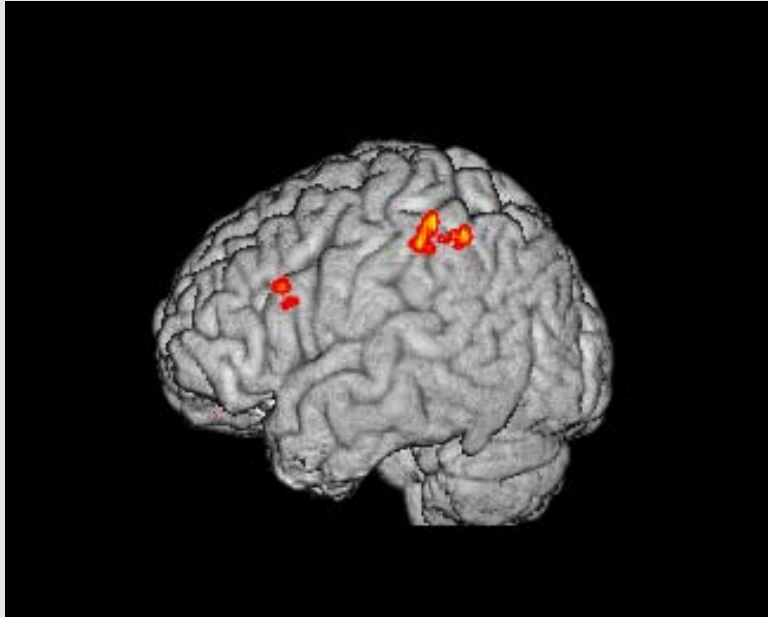
*Before*



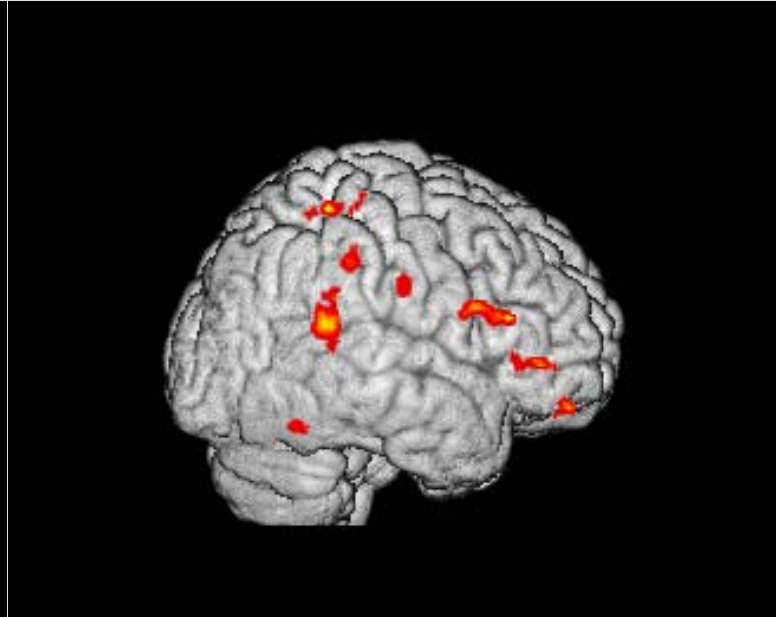
*After*



# *Brain Activity Increases After Intervention*



**left**



**right**



# Magnetic Resonance Imaging (MRI)

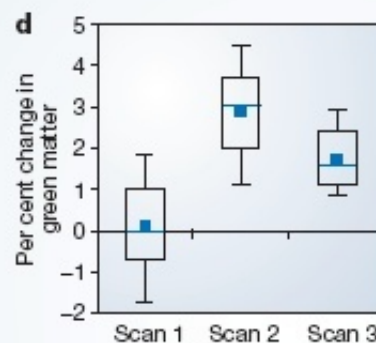
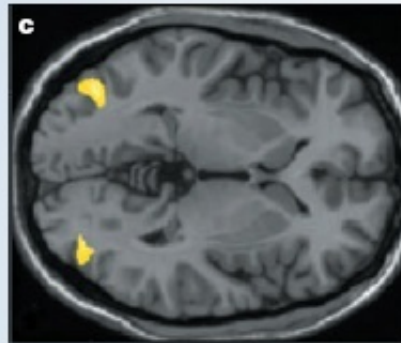
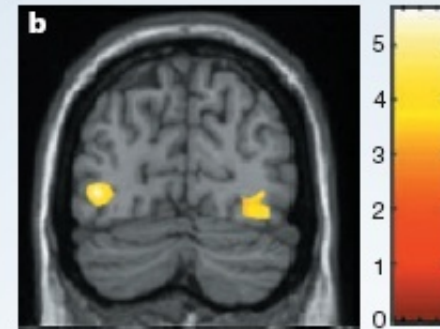
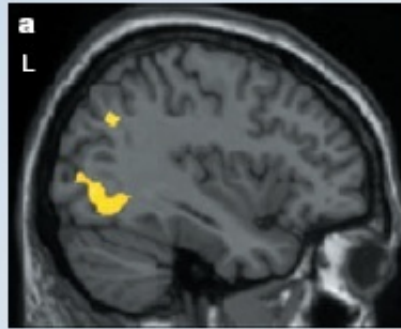
**MRI** studies brain anatomy.



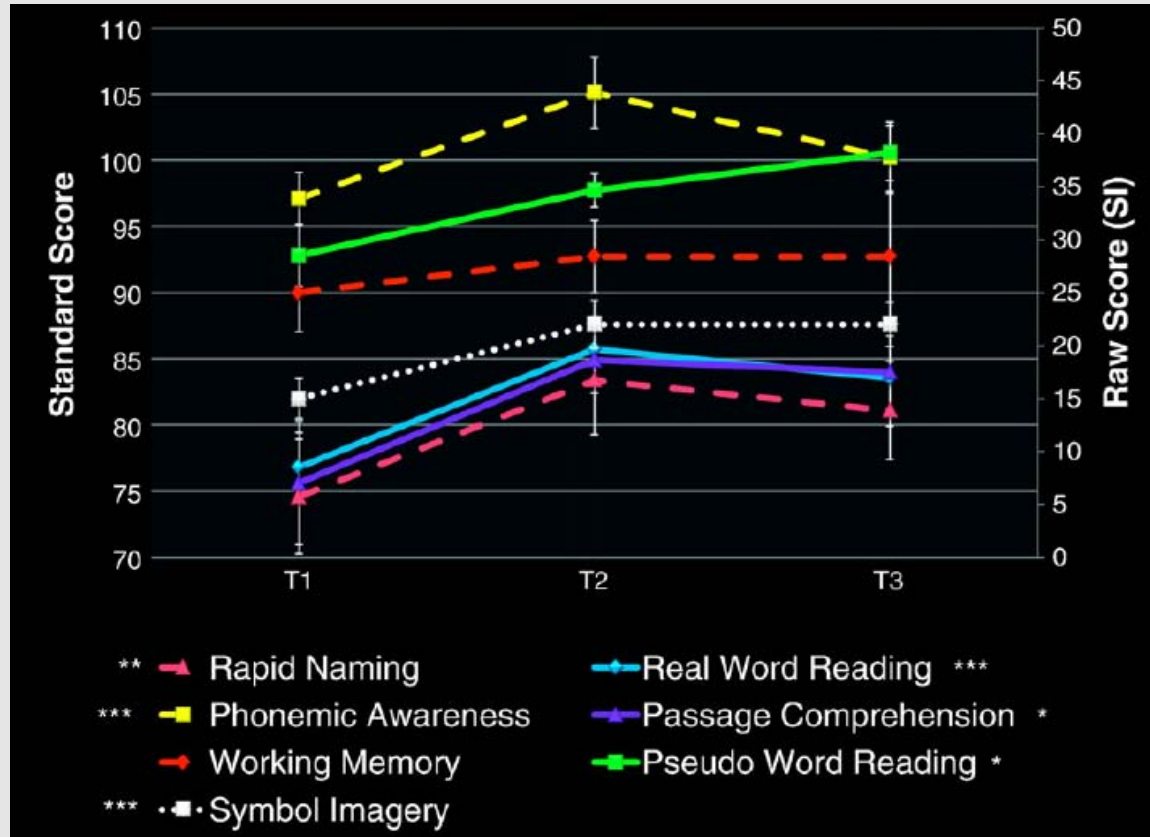
**Functional** MRI (fMRI) studies brain function.



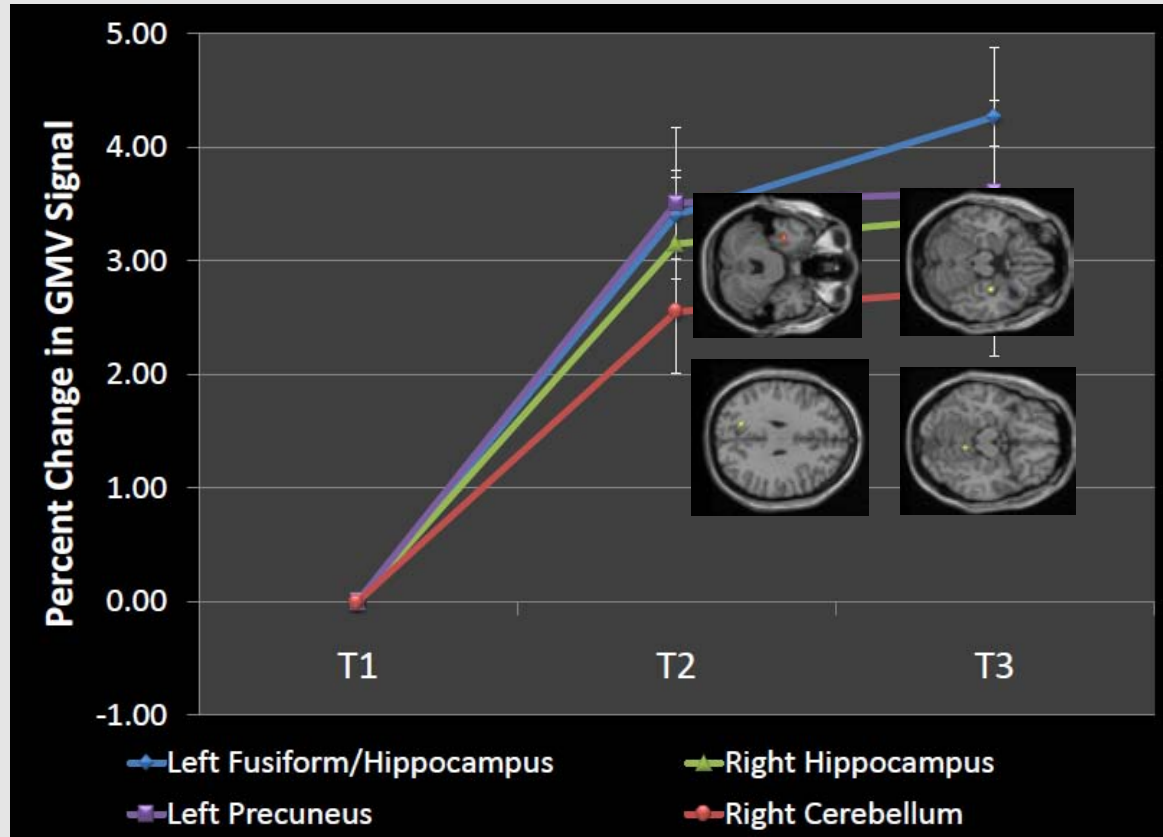
# Changes in Gray Matter Volume After Training



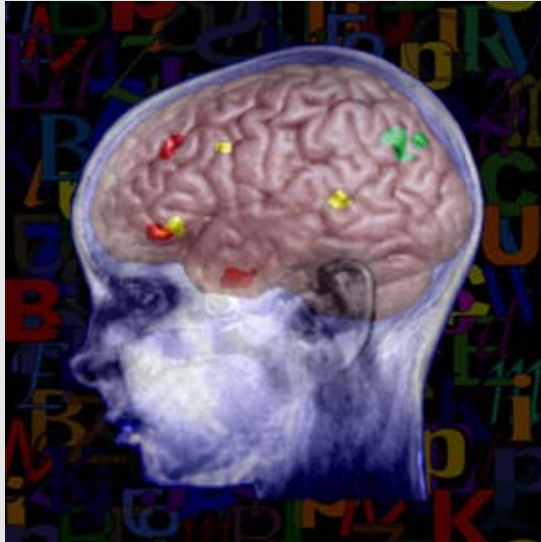
# Reading Scores Increase After Intervention



# Brain Volume Increases After Intervention



# Reading and the Brain



7

Genes

- Environment: Early Language
- Environment: Reading Instruction
- Environment: secondary consequences of reading
- Environment: Other
- Gender



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