Brain Imaging Studies of Reading
Guinevere Eden
Center for the Study of Learning
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**)

---

**Orthography**

**Phonology**

**Semantics**

CAT

/kAT/
Brain Activity During Reading: Adults

Martin et al. (2015)
Brain Activity During Reading: Different Languages

Paulesu et al. (2000)
Brain Activity During Reading: Different Writing Systems

Bolger et al. (2005)
MRI in Children
Reading Outcome Depends On:

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

Scarborough (2001)
Reading Acquisition Rate Is Modulated By:

Language
Orthography
IQ
Social Class
Gender
Quality of Instruction

Goswami (2003)
Brain Activity During Reading: Meta-Analysis

Martin et al. (2015)
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

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
Group Comparison: Controls > Dyslexics

left

right
After Intervention  

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

<table>
<thead>
<tr>
<th>Standard Score</th>
<th>LIPS</th>
<th>EP</th>
<th>P-Pretest</th>
<th>Pre</th>
<th>Post</th>
<th>1 year</th>
<th>2 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre intervention</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Post intervention</td>
<td>Program A</td>
<td>Program B</td>
</tr>
</tbody>
</table>
Skills Targeted by Intervention

*p < .05
Skills Supporting Reading

* $p < .005$
Oral Reading Skills

* \( p < .05 \)

Real Word Reading (WRAT)     Reading Accuracy (GORT)     Reading Rate (GORT)     Reading Comprehension (GORT)

<table>
<thead>
<tr>
<th>Non-Intervention Group</th>
<th>Intervention Group</th>
</tr>
</thead>
</table>

* \( p < .05 \)
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

Draganski et al. (2004)
Reading Scores Increase After Intervention
Brain Volume Increases After Intervention

Krafnick et al. (2011)
Reading and the Brain

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

Genes