Educational Neuroscience:

Brain imaging insights into individual differences in learning

*Bruce McCandliss, PhD*

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**Connecting Education and Neuroscience**

- Brain circuits in experts
- Formation of circuits over development
- Understanding individual differences
- How educational experiences drive changes in brain structure and function

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**Integration of Vision and Language**

- Visual Letters
- Auditory Letters
- Association Areas Supporting Letter-Sound Integration

*Courtesy of Leo Blomert*

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**Brain Studies of Dyslexia:**

A meta-analysis

- 7 studies involving orthographic contrasts
- *p < 0.0001*

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**The expert reader**

- Eye-mind lag less than 200 msec.
- Automatic activation
- Perception of visual word forms
Perceptual Expertise for Visual Word Forms

McCandliss, Cohen, Dehaene (2003)

Attention and brain activity

McCandliss, Cohen, Dehaene (2003)

Visual word processing and experiential origins of functional selectivity in human extrastriate cortex

McCandliss, Cohen, Dehaene (2003)

Attention and brain activity

McCandliss, Cohen, Dehaene (2003)
Focus your attention on:
- matching rhymes
- matching melodies

Electrophysiology

One-Back Activation Task

Maurer, Brandeis & McCandliss (2005)

Reading and Perceptual Expertise

Perceptual Expertise for Visual Words

McCandliss & Posner (1997)
Bentin et al. (1999)

Maurer, Brandeis & McCandliss (2005)
“We cannot understand how the mature system works until we understand how it is constructed in development.”

– Johnson & Pennington (1999)

“Formation of circuits over development:

Before 1st Grade
After 1st Grade
Adults

220 ms
220 ms
150 ms

Maurer et al., (2005)

Individual differences in brain and mind

Individual differences in mind and brain:
Late elementary school years

Words - Symbols N170
Laterality

After Age Regression, p=0.027
Infant ERP (Event Related Potentials)

ERP to speech: 6-month-olds with family history of dyslexia

Pihko, et al., 1999

White Matter Tract Connections

Brain imaging during reading development


White matter tracts in children: from dyslexia to average skill

Niogi & McCandliss (2006)

White matter tracts in children: from average to exceptional skill

Standardized Measures of Short Term Memory

2549
39215
537682
4921357
794293651

"Double Dissociation" in Correlation Patterns

Standardized Word ID  Standardized Digit Recall

y = 0.0026x + 0.1966
R² = 0.4199

y = 0.005x - 0.0332
R² = 0.3125

Short Term Memory

Bilateral Anterior Corona Radiata

CTOPP Standardized Digit Recall

Niogi & McCandliss (2006)
Instruction effects on brain organization?

Word Level Focus Condition

Grapheme-Phoneme Focus Condition

Testing Condition

Impact of Focus of Attention on Learning:

- Learning rate
- Retention
- Generalization
- Brain activity

Effects of Instruction on Learning
Grapheme-Phoneme Focus

Whole Word Focus

Bridging Laboratory and School

Software Based Intervention

Word Building (McCandliss et al, 2003)

t o  p  s a t
  s a p  t a p  t o p
  s t o p  t o p

Word Building (McCandliss et al, 2003)

Word Building (McCandliss et al, 2003)
Word Building (McCandliss et al, 2003)

```
  t o
  sap
```

Word Building (McCandliss et al, 2003)

```
  t o
  sap
```

Word Building (McCandliss et al, 2003)

```
  t o
  a
  s p
```

Word Building (McCandliss et al, 2003)

```
  t o
  a
  s p
```

Word Building (McCandliss et al, 2003)

```
  t o
  a
  s p
```

Word Building (McCandliss et al, 2003)

```
  t o
  a
  s p
```
Reading Novel Words

<table>
<thead>
<tr>
<th>Word</th>
<th>Initial consonant</th>
<th>2nd consonant</th>
<th>3rd consonant</th>
<th>Final consonant</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLURB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STOLT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRGBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Initial consonant

2nd consonant

3rd consonant

Final consonant

Position

Analysis

% Acc.

By Phoneme

Control

Group

McCandliss et al. (2003) Scientific Studies of Reading

Change in Standardized Test Scores—Decoding New Words

Training Effects on Brain Activity

Familiar Words

Novel Words

Control Letters

Left STG

BA 22

-49 -30 12

P < .01

n = 8

Familiar Words

Novel Words

Control Letters

 Change in Standardized Test Scores—Reading Novel Words

NYC Public School Reading Study

60 children, age 8 to 12

Reading scores ranging from 30th to 1st percentile

Random assignment of method and tutors

20 sessions:

- Word Building
  - Grapheme-phoneme focus
- Tutor Guided Reading

fMRI scan before and after tutoring

Change in Standardized Test Scores—Reading Novel Words

Woodcock Johnson Psychoeducational Battery: Word Attack Scores

n = 60

n = 24

Randomized Active Control Study in Schools

University Based Study

n = 24

n = 60
Number Names vs. Number Meanings

Educational Neuroscience
• Functional organization in experts
• Organization of function during development
• Neural correlates of individual differences
• Functional plasticity related to reorganization during intervention

“*We cannot understand how the mature system works until we understand how it is constructed in development, and we cannot fully understand that process of normal construction without understanding how development can go awry.*”

– Johnson & Pennington (1999)

Collaborators

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