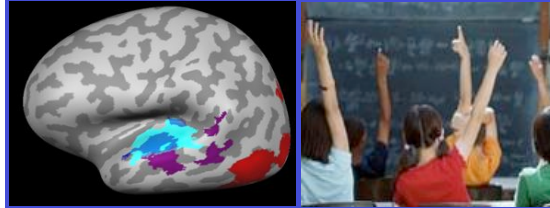


## Educational Neuroscience:

Brain imaging insights into individual differences in learning

*Bruce McCandliss, PhD*

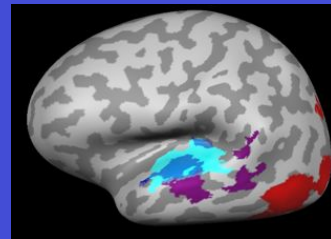
## Connecting Education and Neuroscience



## 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

## Integration of Vision and Language



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

*Courtesy of Leo Blument*

## Brain Studies of Dyslexia:

### A meta-analysis



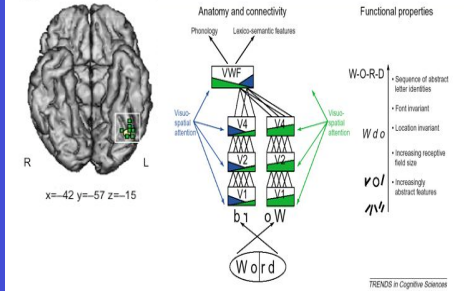
7 studies involving orthographic contrasts

$p < .0001$ )

## The expert reader

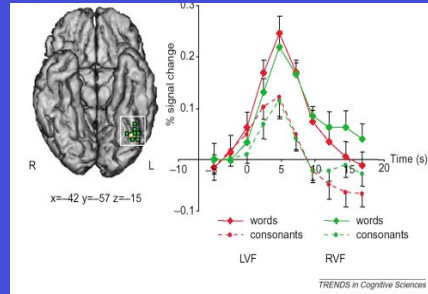
- Eye-mind lag less than 200 msec.
- Automatic activation
- Perception of visual word forms

## Perceptual Expertise for Visual Word Forms



McCandliss, Cohen, Dehaene (2003)

## Perceptual Expertise for Visual Word Forms



McCandliss, Cohen, Dehaene (2003)

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

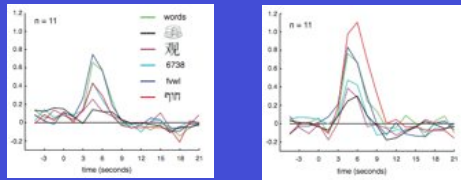
Chris I. Baker<sup>1\*</sup>, Jia Liu<sup>1</sup>, Lawrence L. Wald<sup>1</sup>, Kenneth K. Kwong<sup>1</sup>, Thomas Benner<sup>1</sup>, and Nancy Kanwisher<sup>1,2,3\*</sup>

<sup>1</sup>Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, 10 Center Drive, Building 10, Room 4C104, Bethesda, MD 20892; <sup>2</sup>State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China; <sup>3</sup>Massachusetts General Hospital/Massachusetts Institute of Technology Harvard Medical School Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, 120 Street, Charlestown, MA 02128; and <sup>4</sup>McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139

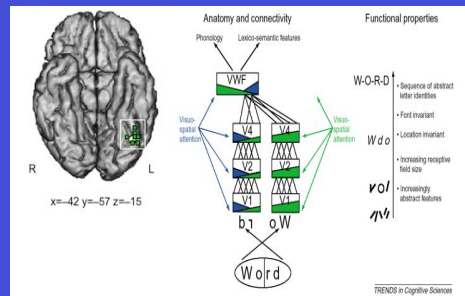
Contributed by Nancy Kanwisher, April 11, 2007 (sent for review March 13, 2007)

www.pnas.org/cgi/doi/10.1073/pnas.070300104

PNAS | May 22, 2007 | vol. 104 | no. 21 | 9087-9092

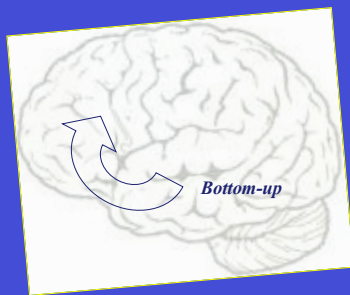


## Perceptual Expertise for Visual Word Forms

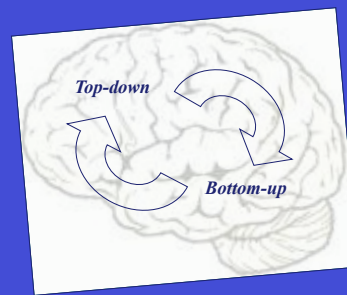


McCandliss, Cohen, Dehaene (2003)

## Attention and brain activity



## Attention and brain activity



## Attending to sounds within words

Focus your attention on:

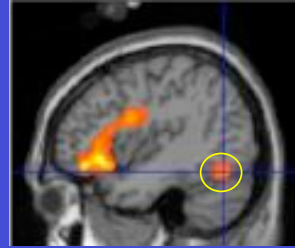
- matching rhymes



- matching melodies



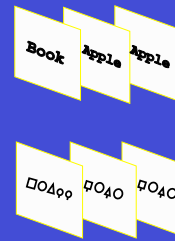
## Attending to sounds within words



## Electrophysiology

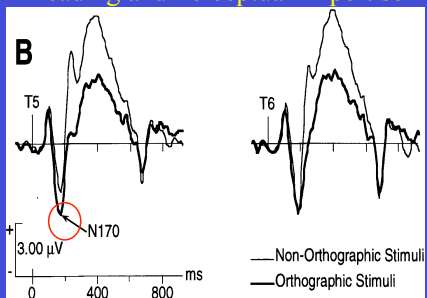


## One-Back Activation Task



Maurer, Brandeis & McCandliss (2005)

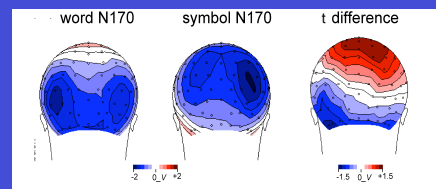
## Reading and Perceptual Expertise



McCandliss & Posner (1997)

Bentin et al. (1999)

## Perceptual Expertise for Visual Words



Maurer, Brandeis & McCandliss (2005)

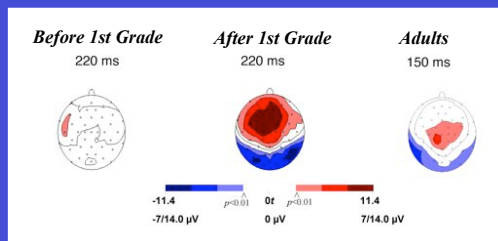
*“We cannot understand how the mature system works until we understand how it is constructed in development”;*

– Johnson & Pennington (1999)

### Formation of circuits over development



### Formation of circuits over development



Maurer et al., (2005)

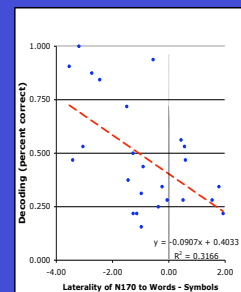
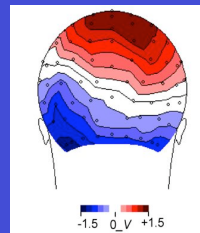
### Individual differences in brain and mind

*“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)

### Individual differences in mind and brain: Late elementary school years

**Words - Symbols N170 Lateralization**

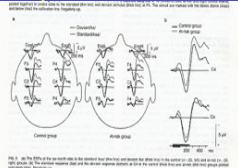


After Age Regression,  $p=0.027$

## Infant ERP (Event Related Potentials)

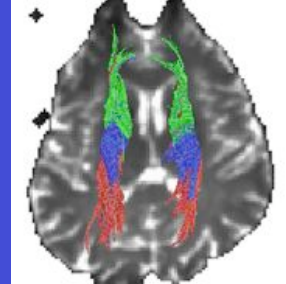


ERP to speech:  
6-month-olds  
with family history  
of dyslexia

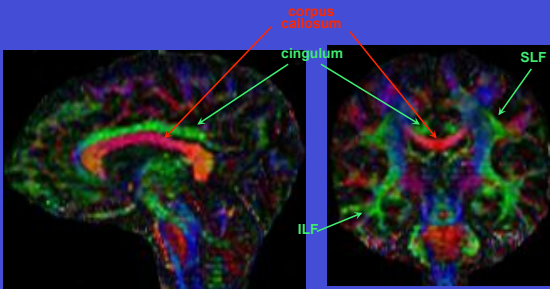


Pihko, et al., 1999

## White Matter Tract Connections



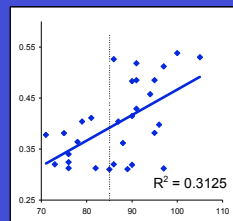
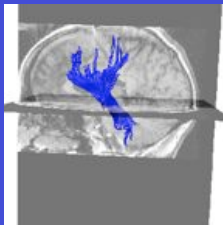
## White Matter Tract Connections



## Brain imaging during reading development

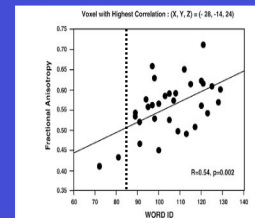
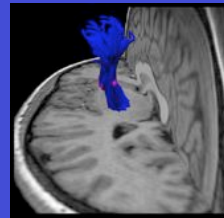


## White matter tracts in children: from dyslexia to average skill



Niogi & McCandliss (2006)

## White matter tracts in children: from average to exceptional skill



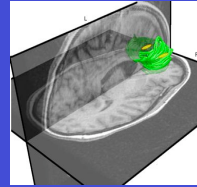
Beaulieu, et al., (2005) NeuroImage

## Standardized Measures of Short Term Memory

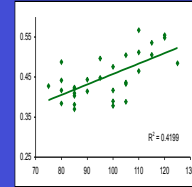
2 5 4 9  
 3 9 2 1 5  
 5 3 7 6 8 2  
 4 9 2 1 3 5 7  
 7 9 4 2 9 3 6 5 1

## Short Term Memory

Bilateral Anterior  
 Corona Radiata



CTOPP Standardized  
 Digit Recall

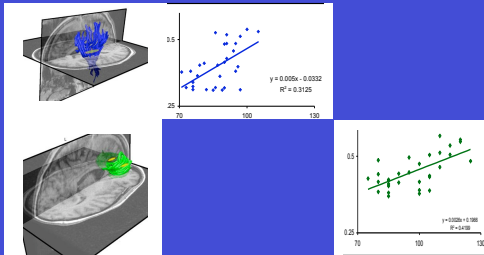


Niogi & McCandliss (2006)

## “Double Dissociation” in Correlation Patterns

Standardized  
 Word ID

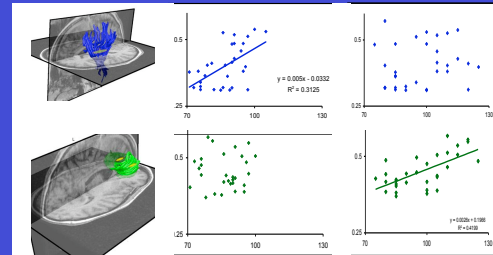
Standardized  
 Digit Recall



## “Double Dissociation” in Correlation Patterns

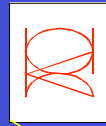
Standardized  
 Word ID

Standardized  
 Digit Recall



## Instruction effects on brain organization?

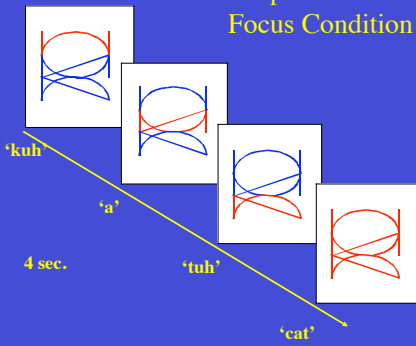
### Word Level Focus Condition



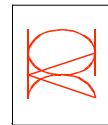
'cat'

4 sec.

### Grapheme-Phoneme Focus Condition



### Testing Condition



500 ms

Target ("CAT") or Foil (i.e. "KID")

Keypress  
(endorse or reject)

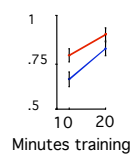
## Impact of Focus of Attention on Learning:

- Learning rate
- Retention
- Generalization
- Brain activity

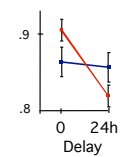
## Effects of Instruction on Learning

Grapheme-Phoneme (blue line) Whole Word (red line)

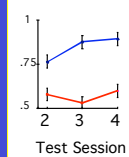
### Initial Learning

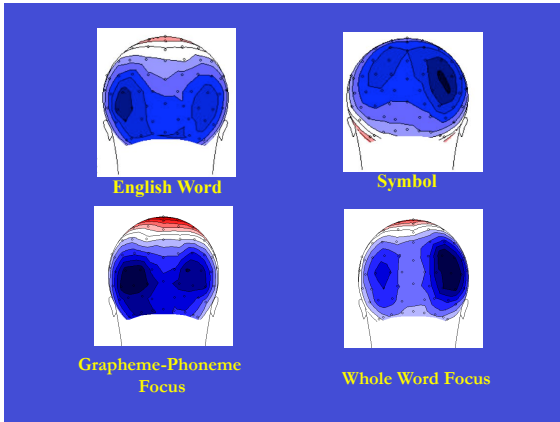


### 24 Hour Delay



### Transfer





# Bridging Laboratory and School

### Software Based Intervention

Take the "a" away and put the "i" in the middle

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

o

s a t

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)

t

o

p

s a

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)

t

o

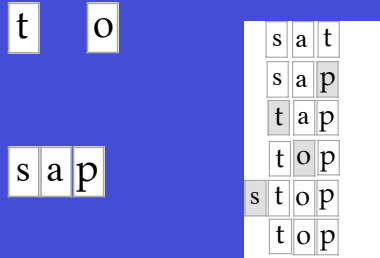
p

s a

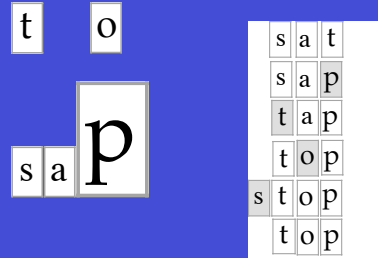
s	a	t	
s	a	p	
t	a	p	
t	o	p	
s	t	o	p
t	o	p	



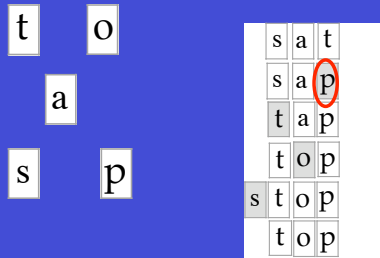
Word Building (McCandliss et al, 2003)



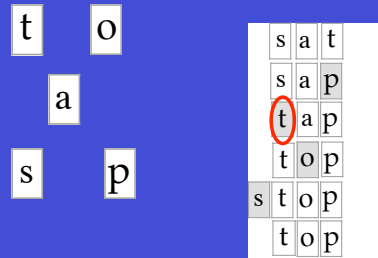
Word Building (McCandliss et al, 2003)



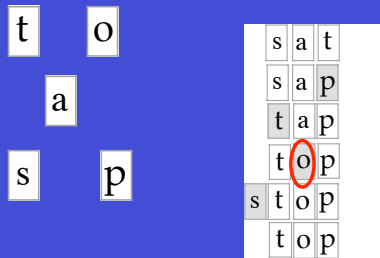
Word Building (McCandliss et al, 2003)



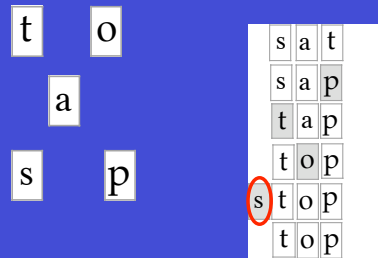
Word Building (McCandliss et al, 2003)



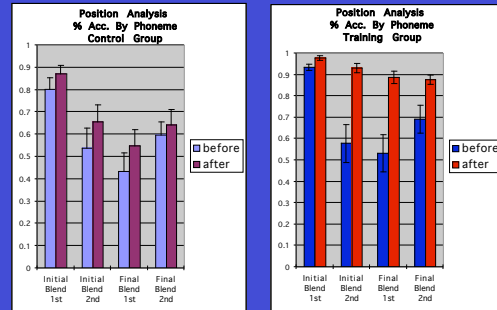
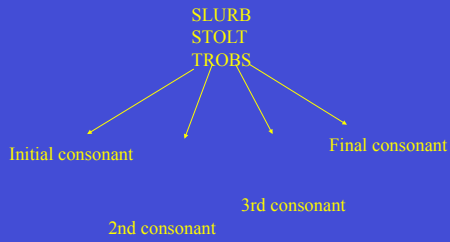
Word Building (McCandliss et al, 2003)



Word Building (McCandliss et al, 2003)

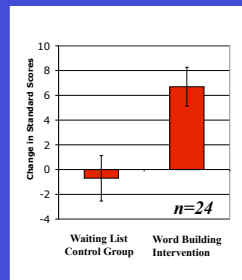


## Reading Novel Words

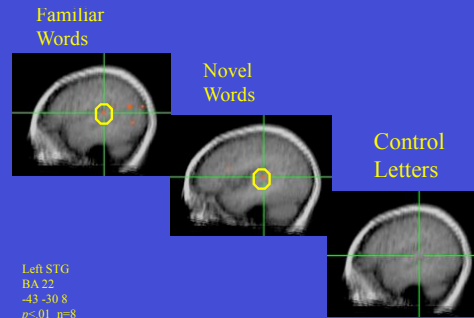


McCandliss et al. (2003) Scientific Studies of Reading

## Change in Standardized Test Scores—Decoding New Words



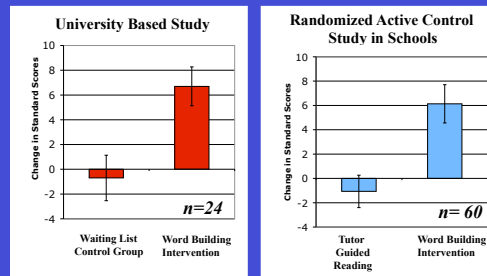
## Training Effects on Brain Activity



## NYC Public School Reading Study

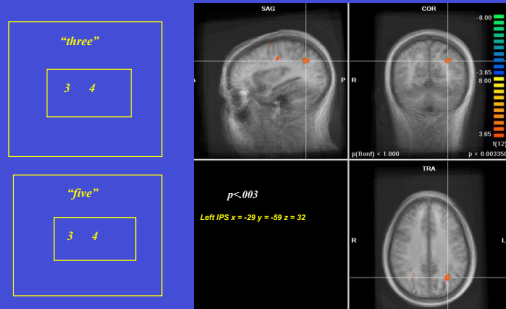
60 children, age 8 to 12  
Reading scores ranging from 30th to 1st percentile  
Random assignment of method and tutors  
20 sessions:  
-Word Building  
  -(Grapheme-phoneme focus)  
-Tutor Guided Reading  
  -(Comprehension focus)  
fMRI scan before and after tutoring

## Change in Standardized Test Scores—Reading Novel Words



Woodcock Johnson Psychoeducational Battery: Word Attack Scores

## 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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Jason Zevin  
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Eva Hulse  
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Jamie Ferri  
Cathy Yan

### Weill Medical-CBIC

Richard Watts  
Aziz Ulug  
Henning Voss