Bridging Brain, Mind, and Behavior

The Fundamental Role of Behavioral Science in Understanding the Mind-Brain

Siegler Quote

Cognitive science provides and empirically based technology for determining people's existing knowledge, for specifying the form of likely future knowledge states, and for choosing the types of problems that lead from present to future knowledge.

- D. Klahr & R. Siegler

Brain and Behavior

An analysis at the behavioral level lays the foundation for an analysis at the neural level. Without this foundation, there can be no meaningful contribution from the neural level.

- Randy Gallistel

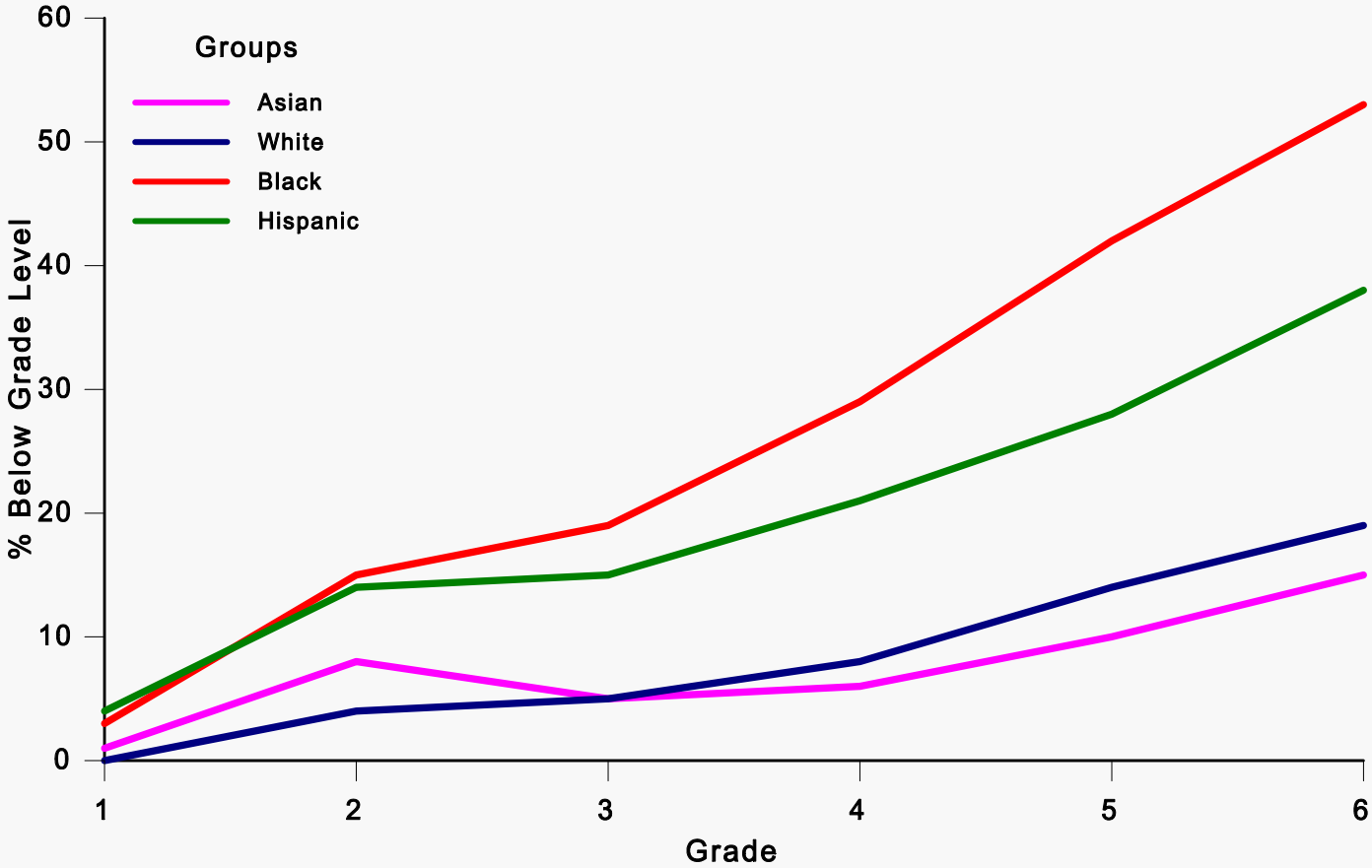
Spans in the Bridge

- Analyze behavior into sub-components
- Develop models of the mental processes that implement and orchestrate the sub-components
- Use theses models, cognitive models, to explore the brain structures that implement the mental processes

Crossing the Bridge: Outline

- Take elementary arithmetic as a behavior.
- Cognitive models of arithmetic allow us to identify and correct learning problems.
- The same cognitive models allow us to study which brain structures support arithmetic reasoning.
- Reconciling recent brain imaging studies of bilinguals requires understanding behavior.

Students Below Grade Level in Math by Racial /Ethnic Group

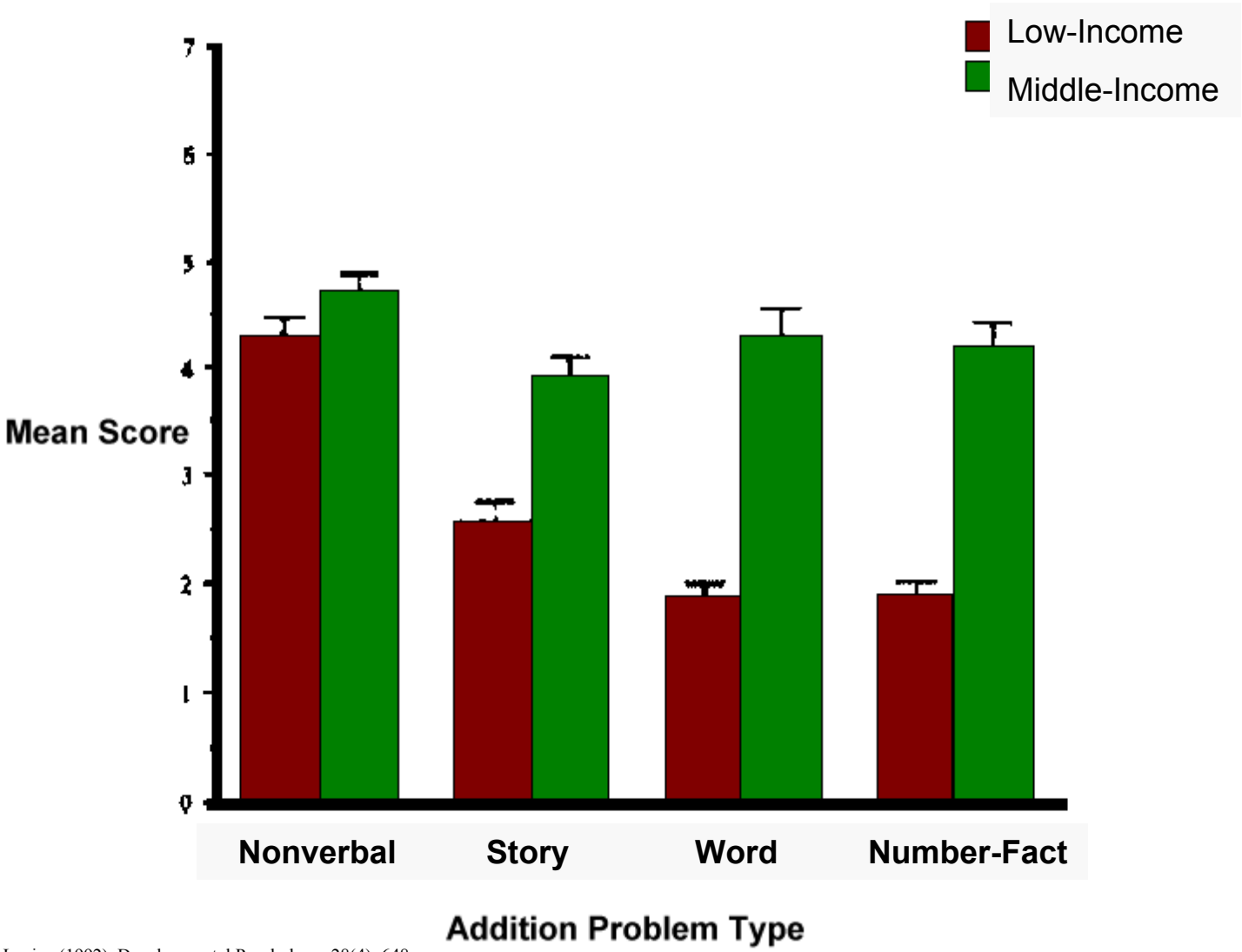


NSF Survey of 28,000 students, Montgomery County, MD (Science, Vol 241, p. 408, 22 July 1988)

Why do student perform well or poorly?

- Positive indicators
  - Parental attitudes and encouragement
  - Teacher encouragement
  - Student's liking for the subject
- Negative factors affecting minorities
  - Economic factors
  - Fragmentation of families
  - Teachers beliefs about abilities

Nonverbal vs. Verbal Representations



Jordan, Huttenlocher & Levine (1992). Developmental Psychology 28(4): 648

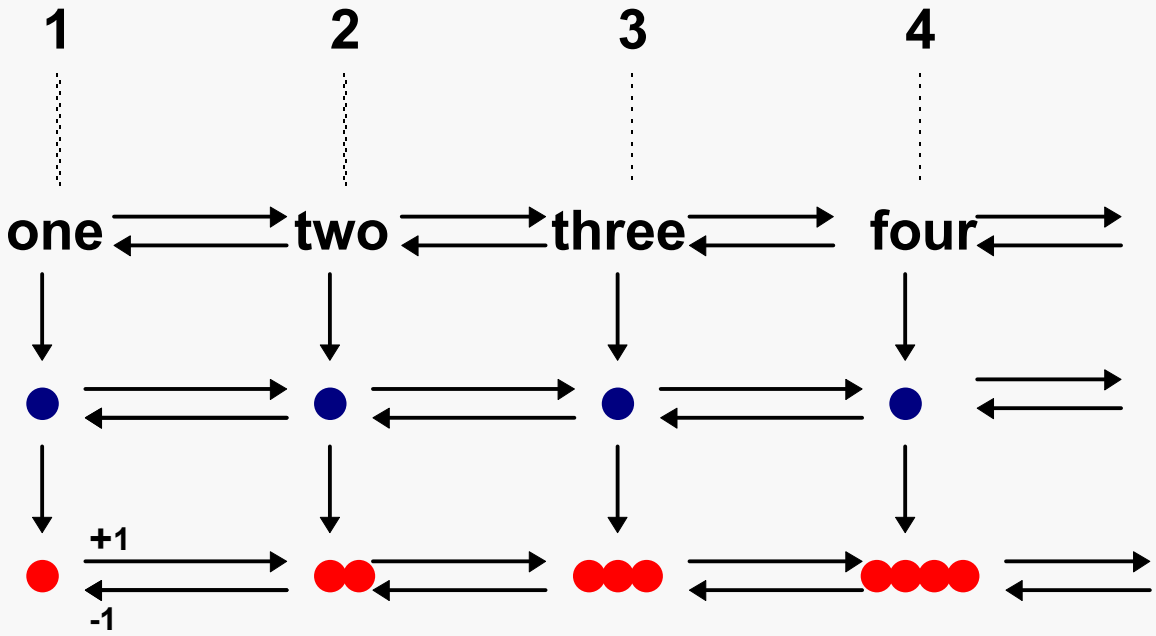
Kindergartner's Performance on Number Knowledge Test (% Correct)

Item	High SES	Low SES
Here's a candy. Here are 2 more How many do you have?	100	92
Which pile has more? (Show two piles of chips.)	100	93
How many triangles are there? (Show mixed array of triangles/circle.)	85	79
If you had 4 candies and received 3 more, how many would you have?	72	14
What comes two numbers after 7?	64	28
Which number is bigger/smaller? (Show two Arabic digits.)	96	18

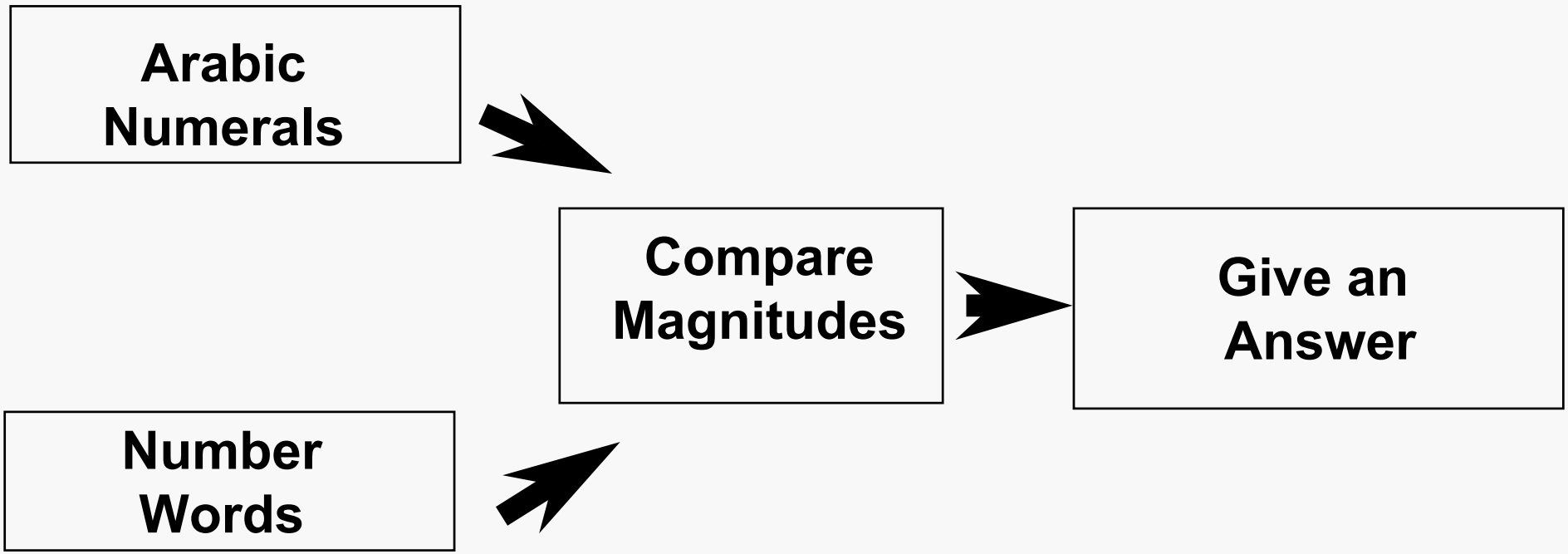
3 Representations of Number

- Arabic numerals - a written representation that facilitates calculation
- Number words - a verbal representation for counting and for simple mental arithmetic
- Analog magnitudes - a preverbal representation (shared with some animals) that permits comparison of quantities

Integrating the Representations: the Mental Number Line



Understanding Numerical Comparison



Possible Cognitive Diagnosis

Some children begin school without learning or understanding how the verbal representation of number maps onto their innate analog magnitude representation of quantity.

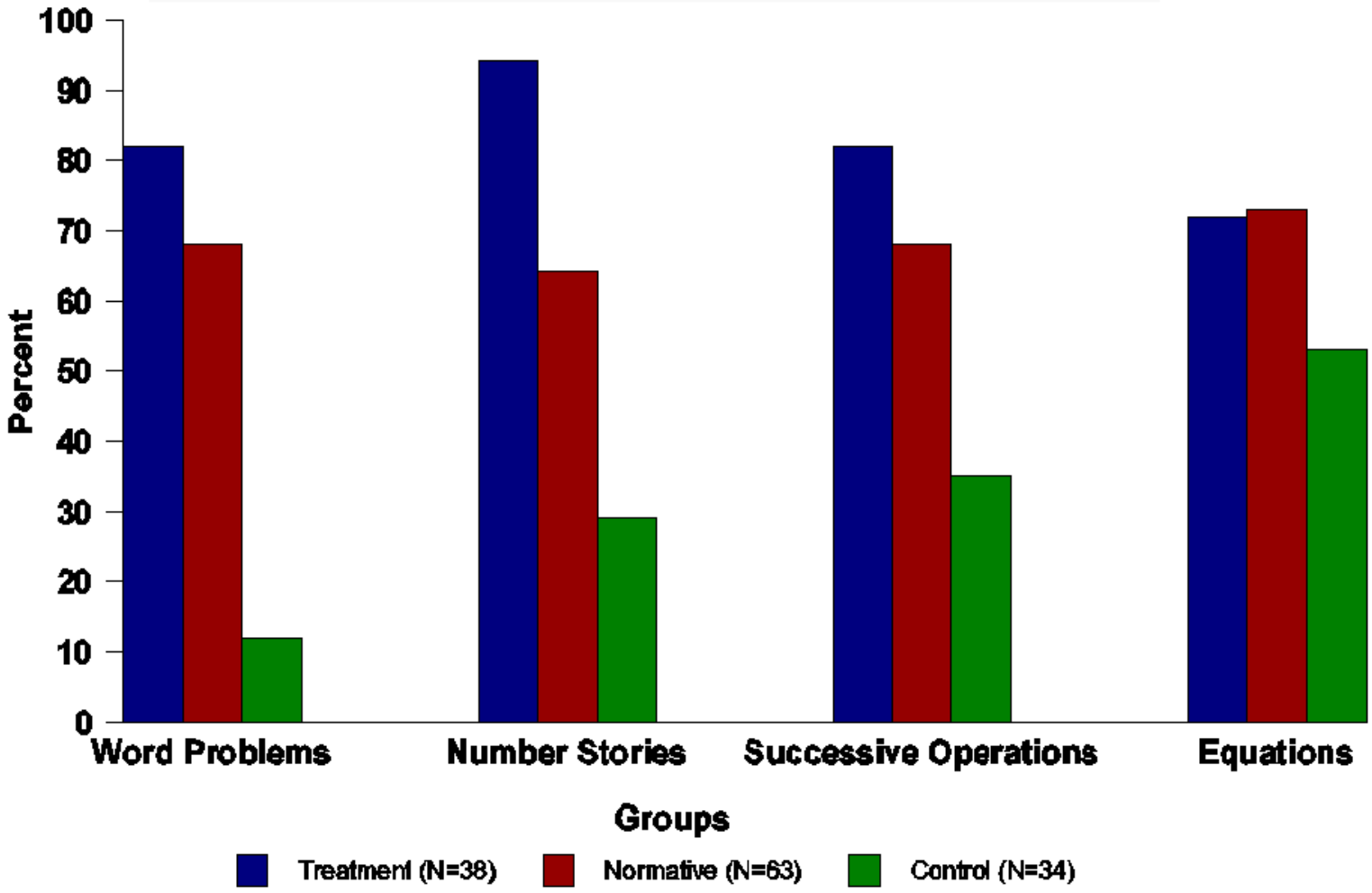
Mean Scores (s.d) on Number Knowledge Test Pre- and Post Number Worlds Instruction

Group	Pre-K	Post-K	Post-Gr. 1
Treatment 1	6.3(2.5)	11.2(2.7)	16.5(3.0)
Treatment 2	5.7(2.5)	12.1(1.9)	17.4(2.0)
Control 1	7.2(2.4)	8.9(2.4)	12.5(2.8)
Control 2	7.2(2.0)	9.3(2.8)	14.3(2.9)
Norm 1	9.8(3.2)	11.4(2.8)	16.9(4.0)
Norm 2	10.6(1.7)	13.5(2.9)	18.8(2.9)

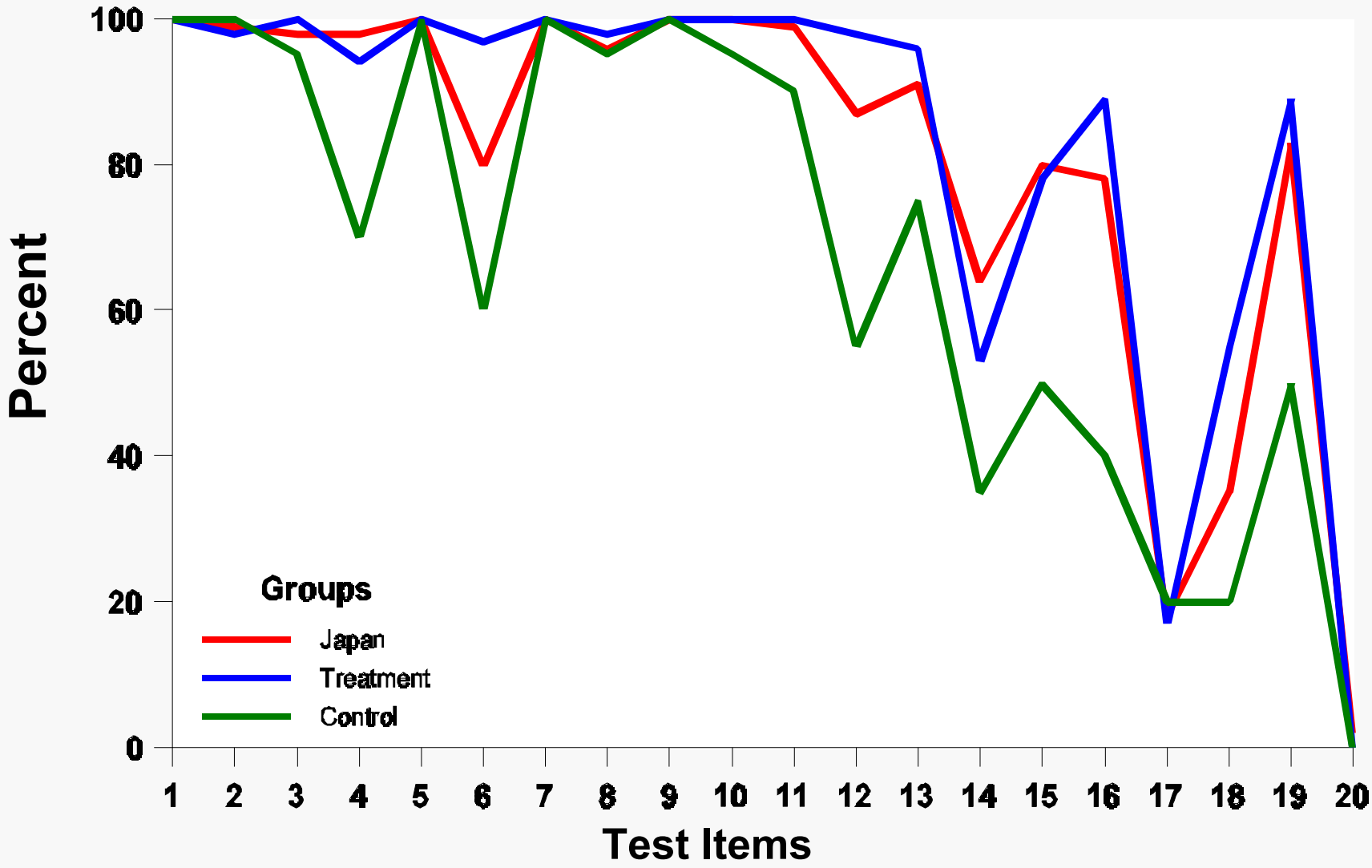
Expected Score: K = 9 - 11; Grade 1 = 16 -18

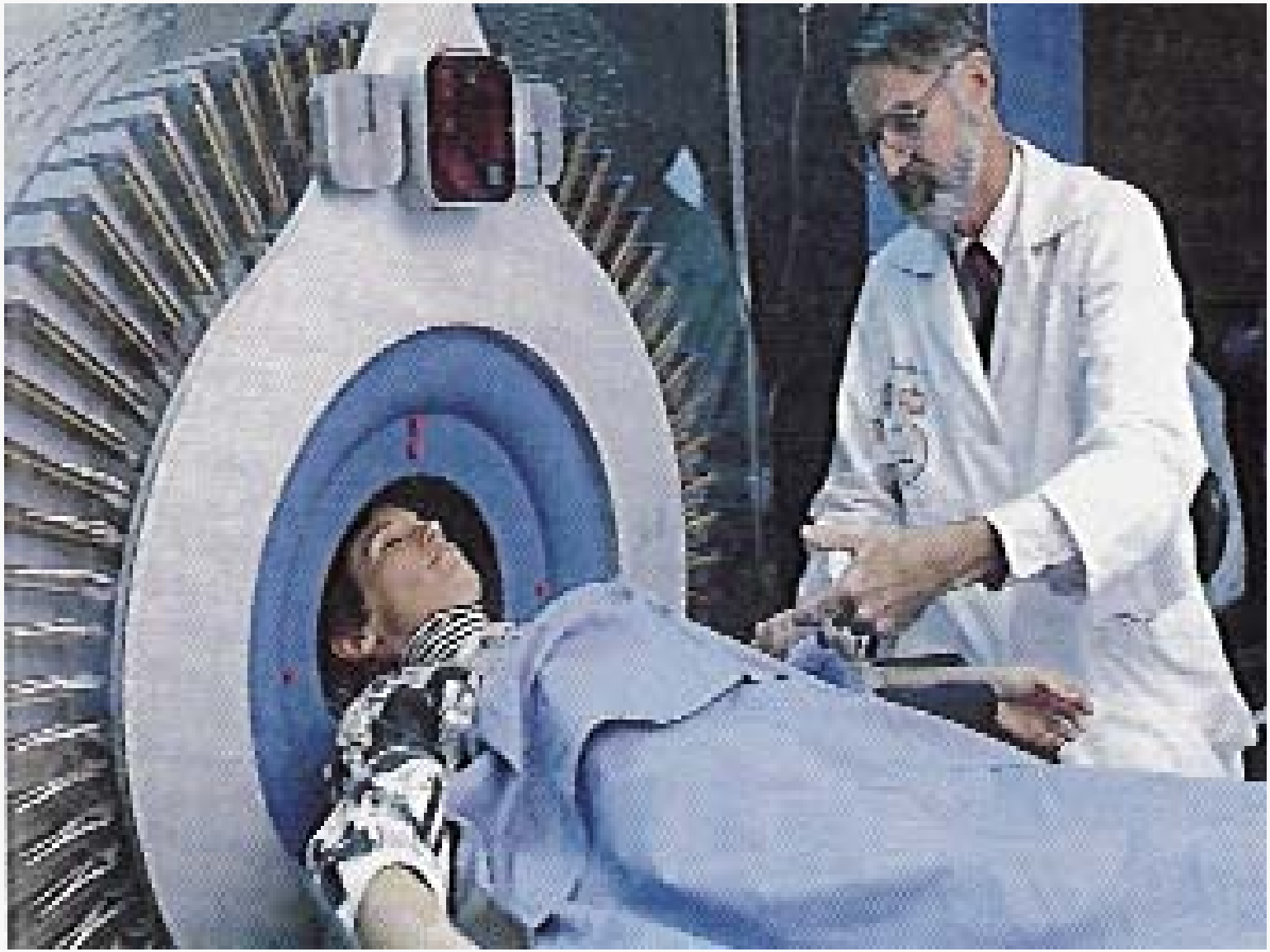
From S. Griffin and R. Case, Teaching Number Sense, Table 3, Yr. 2 report, August 1993

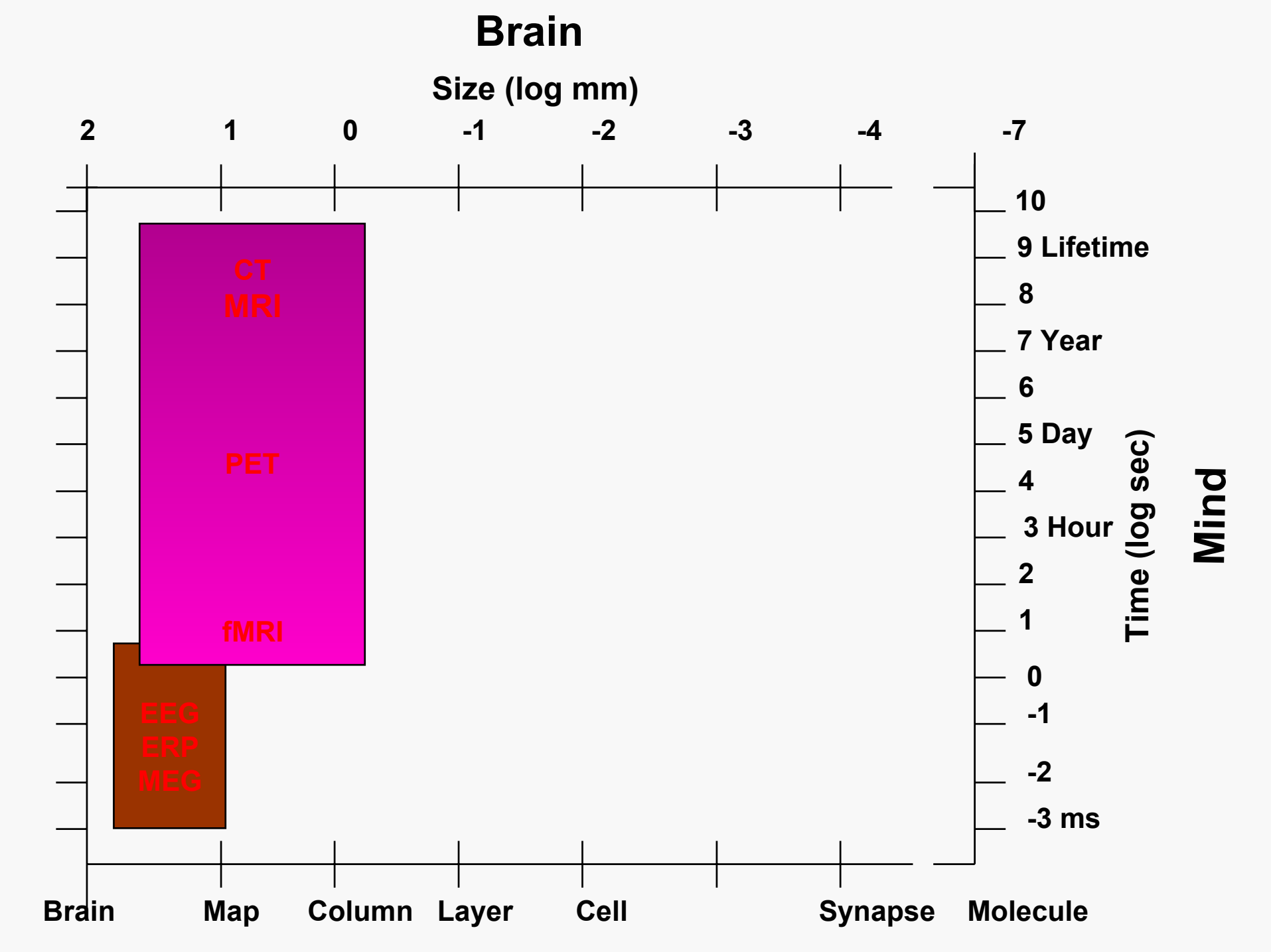
Number Sense Tests: % Passing at End of Grade 1



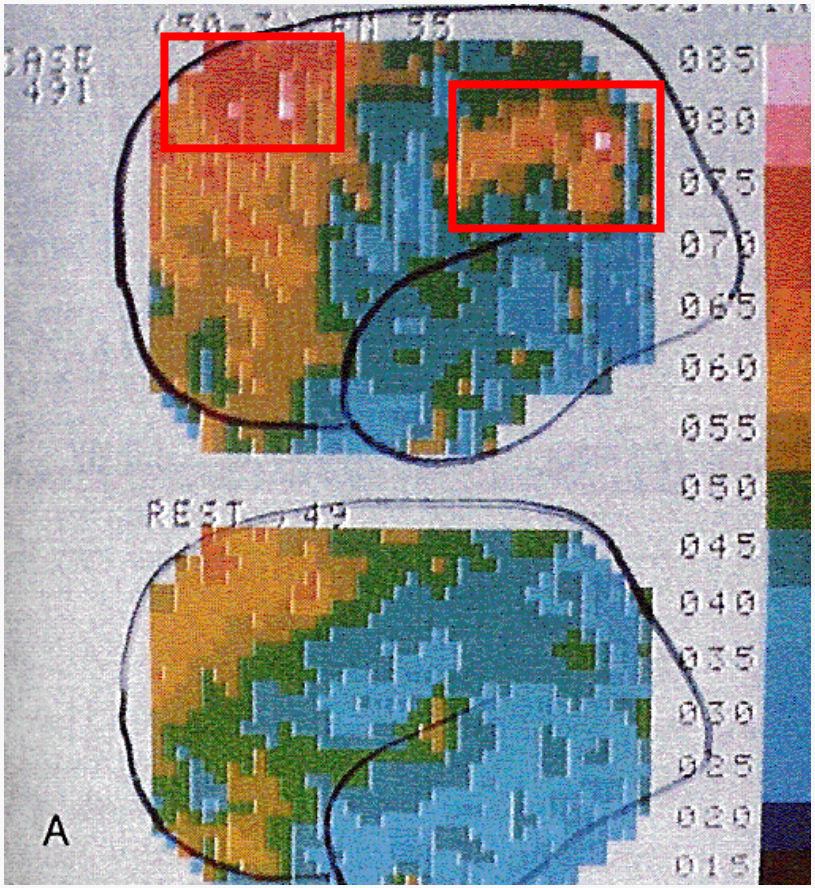
International Computation Test: % First Graders Passing Items 1-20



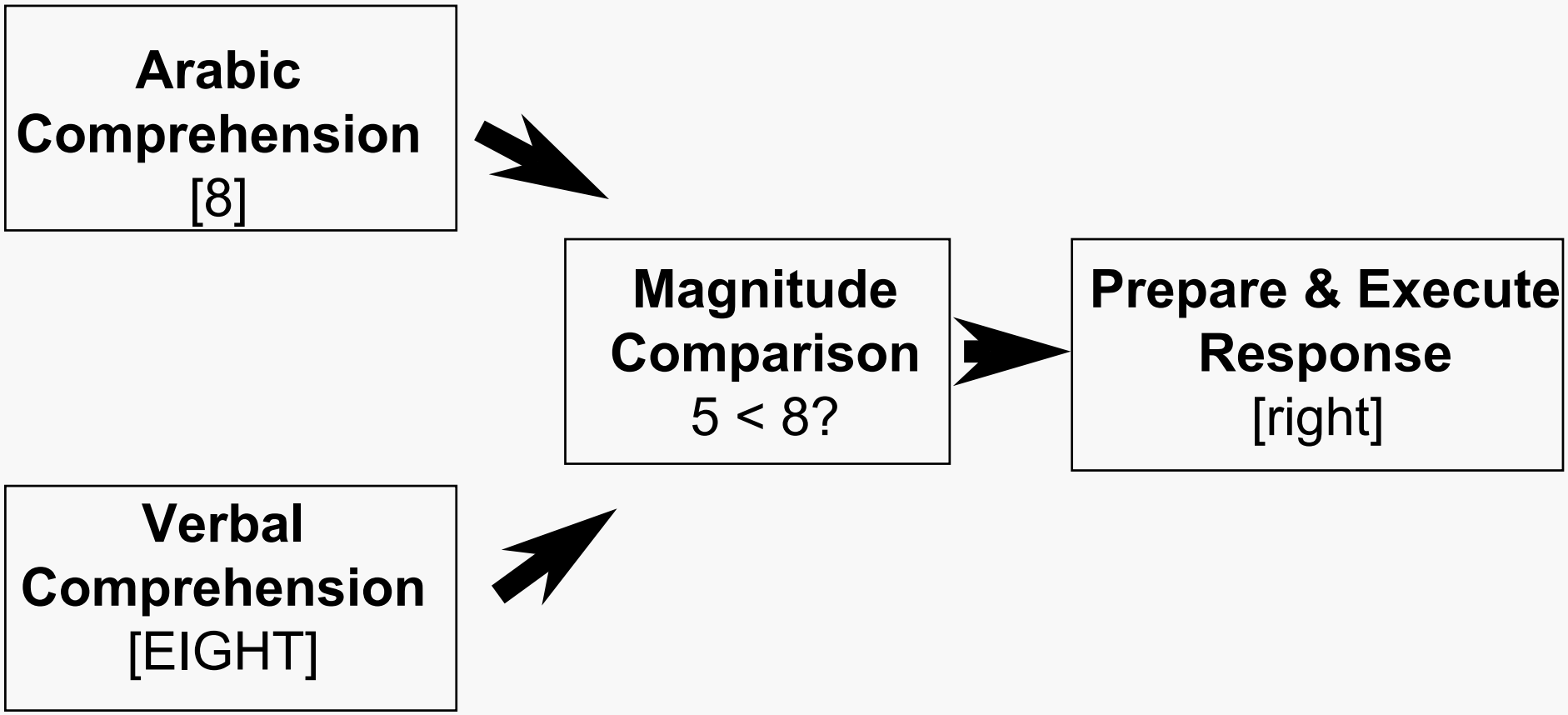



Brain
Size (log mm)
2
1
0
-1
-2
-3
-4
-7
CT
MRI
PET
fMRI
EEG
ERP
MEG
10
9 Lifetime
8
7 Year
6
5 Day
4
3 Hour
2
1
0
-1
-2
-3 ms
Time (log sec)
Mind
Brain
Map
Column
Layer
Cell
Synapse
Molecule

Count backward from 50 by 3s



Roland & Friberg (1985) J. of Neurophysiology 53(5):1227

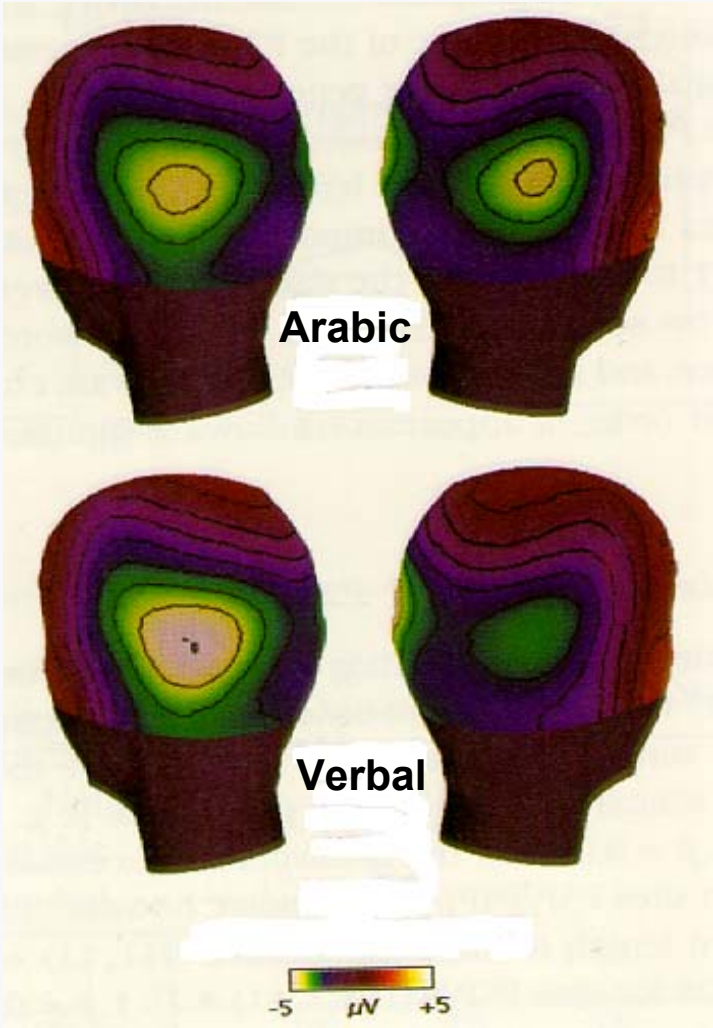


Identification
Notation effect
(arabic vs. verbal)

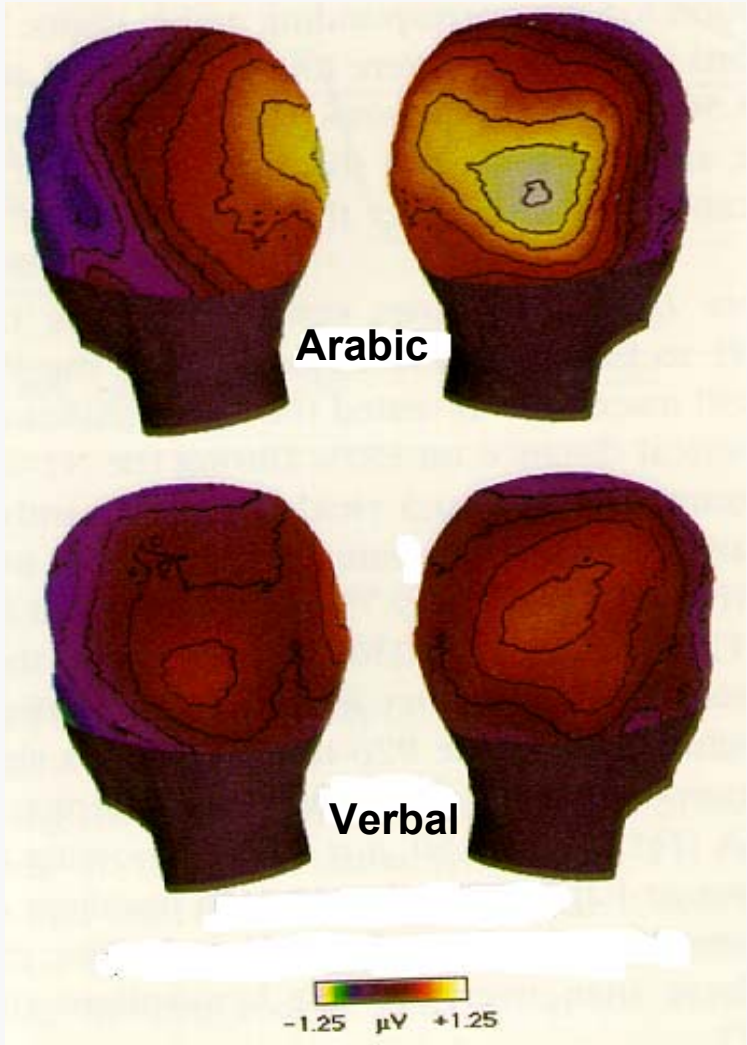
Comparison
Distance effect
(close vs. far)

Response
Response-side effect
(left vs. right)

(S. Dehaene, J. Cognitive Neuroscience, 8(1), p49, 1996)



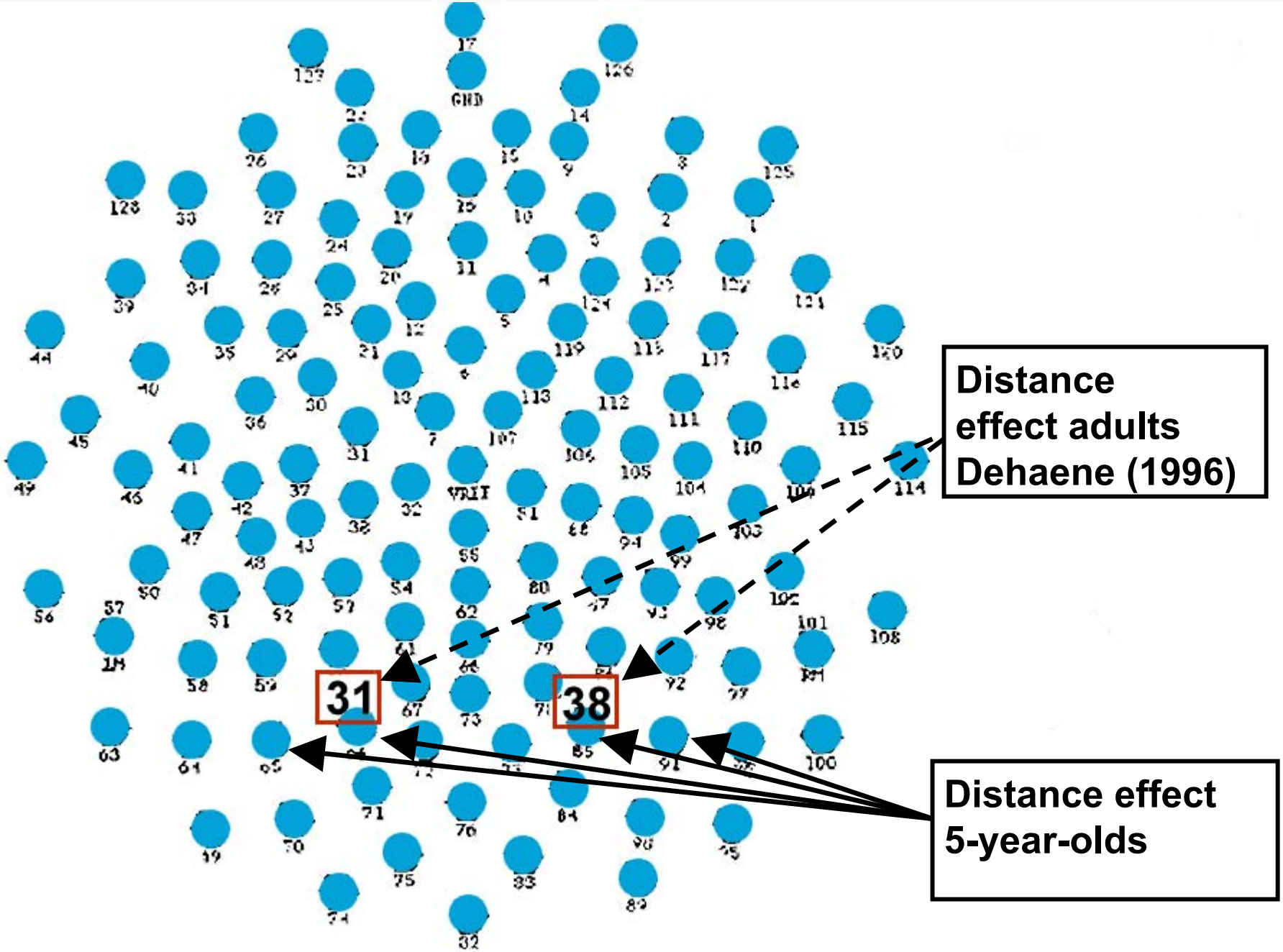
Notation Effect



Distance Effect

210 ms before key press

(S. Dehaene, J. Cog. Neuroscience, 8(1), p.56, 1996)



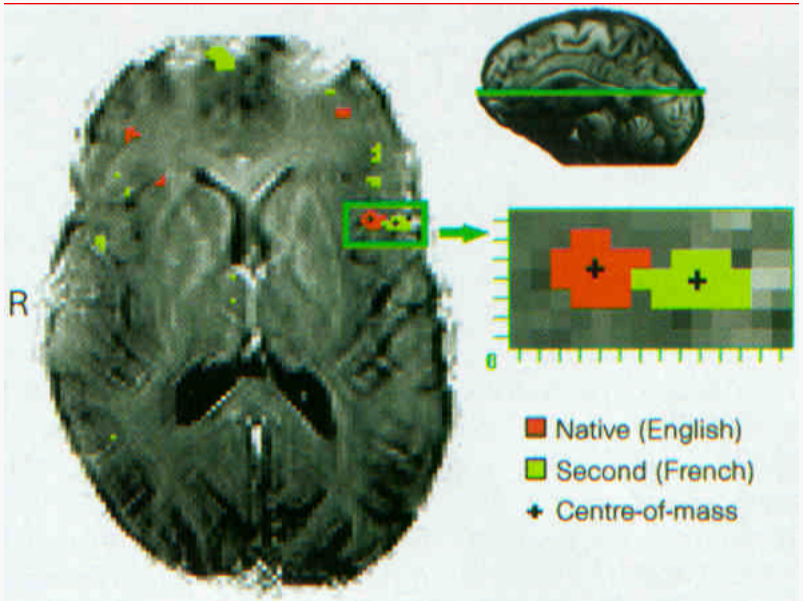
Temple & Posner 1998, PNAS 95: 7837

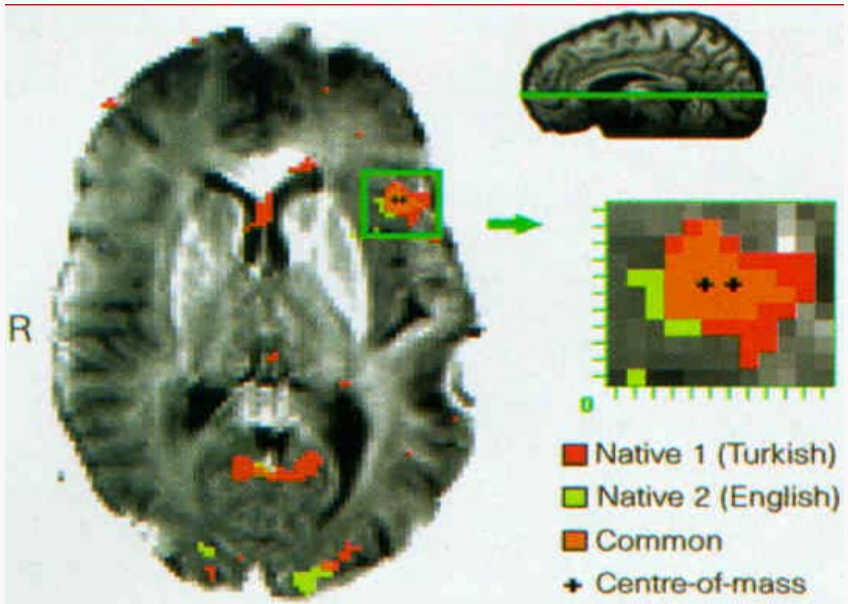
What do we learn from this?

- Bilateral neural system for Arabic numeral representation
- Right hemisphere neural system for abstract magnitude representation
- Numerical comparison is a right hemisphere task that uses the magnitude representation
- Analyzing observed behavior into its mental sub-components allows us to understand how brain circuits support behavior

Science Times
The New York Times
D1
TUESDAY, AUGUST 24, 1999

Second Language Learned Early Stored in Child's Brain Like Native Language





fMRI images show that a second language learned late is represented in different brain areas than a second language learned in infancy. Left image shows different areas of activation when second language learned late. Right image shows common area for two languages when both are learned in infancy.

Science Times
The New York Times
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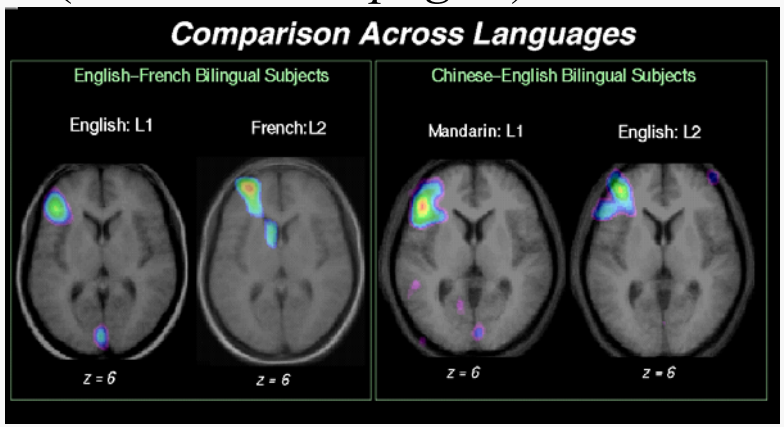
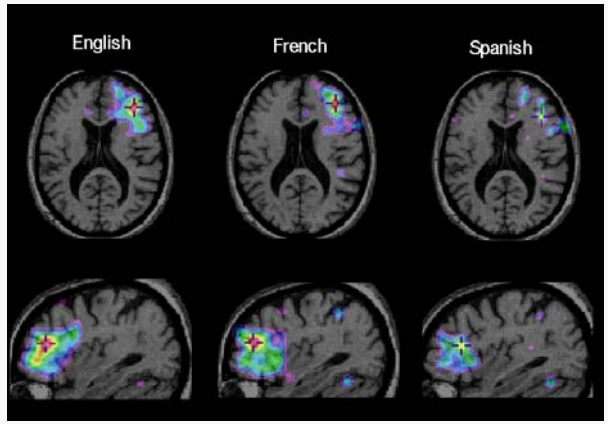
TUESDAY, AUGUST 24, 1999

Second Language Learned Late Activates Same Brain Areas as First Language

PET studies of bilinguals done at the Montreal Neurological Institute have revealed that in fluent multi-linguals the same brain areas are active when using words in each of their languages, even when the languages are as distinct as English and Mandarin and even when the second language is learned late in life. (*Continued on page 6)*





PET image at right shows that the same brain areas are active when processing words in subjects' first or second language even when the second language is learned late (French after at age 7, English at age 12). At left, PET images of a trilingual's brain, who acquired Spanish and French in infancy, but English at age 9.

Science Times

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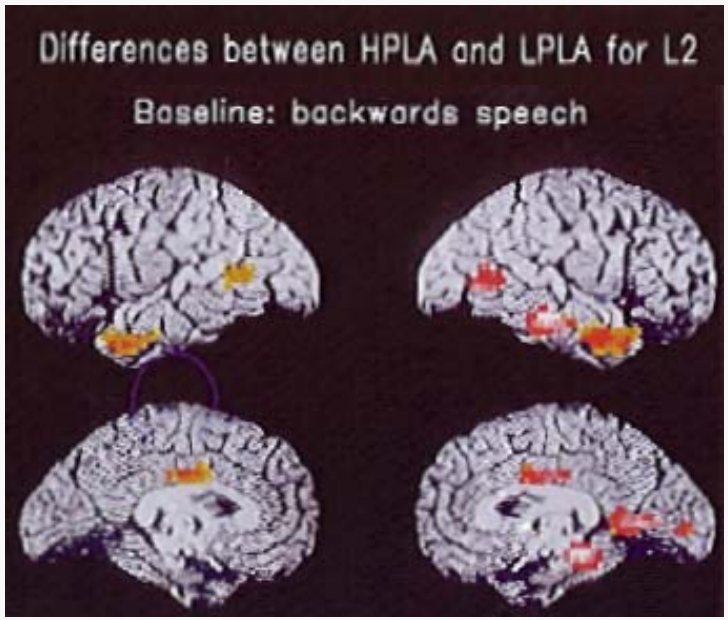
TUESDAY, AUGUST 24, 1999

The New York Times

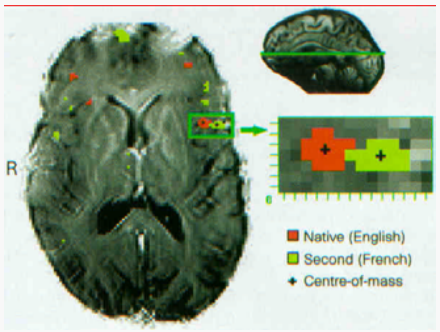
Second Languages and the Brain: Proficiency not Age of Learning Matters



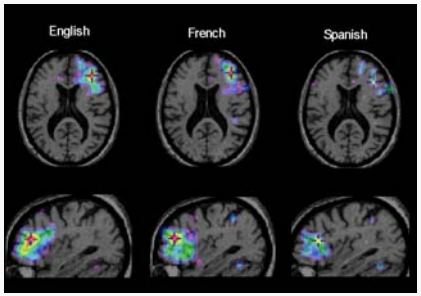
Brain images showing differences in second language processing for skilled vs. unskilled late bilinguals. The study found no differences for skilled late vs. early bilinguals.

In a series of fMRI studies, a group of European scientists have found the a person's skill or proficiency in using a second language is more important than age of learning the second language in determining how a second language is organized in the brain. Their results raise questions about critical periods for language learning. The study

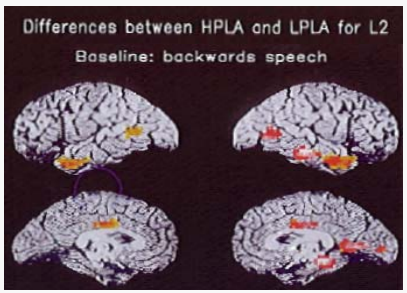
What Were the Subjects Doing?



Covert **sentence production** task: When given a cue (sun, moon), imagine speaking L1 or L2 (as directed) to describe events that occurred the previous day or the previous evening.



Overt **word-level semantic production** task: Repeat visually presented words in L1 or L2 on some trials and generate a verb that goes with a noun (saw - cut) in L1 or L2 on other trials.



Overt **language comprehension** task: Listen to stories presented aurally in L1, L2, and a third unknown language so as to be able to answer questions about a story after hearing it..

The Future Challenge for Mind-Brain Science

The challenge for the future is to understand at a deeper level the actual mental operations assigned to the various areas of [brain] activation. Before this goal can be achieved, the experimental strategies used in PET studies must be refined so that more detailed components of the process can be isolated.

- M. Posner & M. Raichle, 1994

PowerPoint Presentation
available on-line at

www.jsmf.org