WELCOME

The Neuroscience of Learning:
Brain Fitness for all Ages

KENTUCKY ASSOCIATION OF SCHOOL ADMINISTRATORS
CONNECTING NEXT GENERATION
LEARNERS AND LEADERS
43RD ANNUAL SUMMER INSTITUTE • JULY 13–15, 2011

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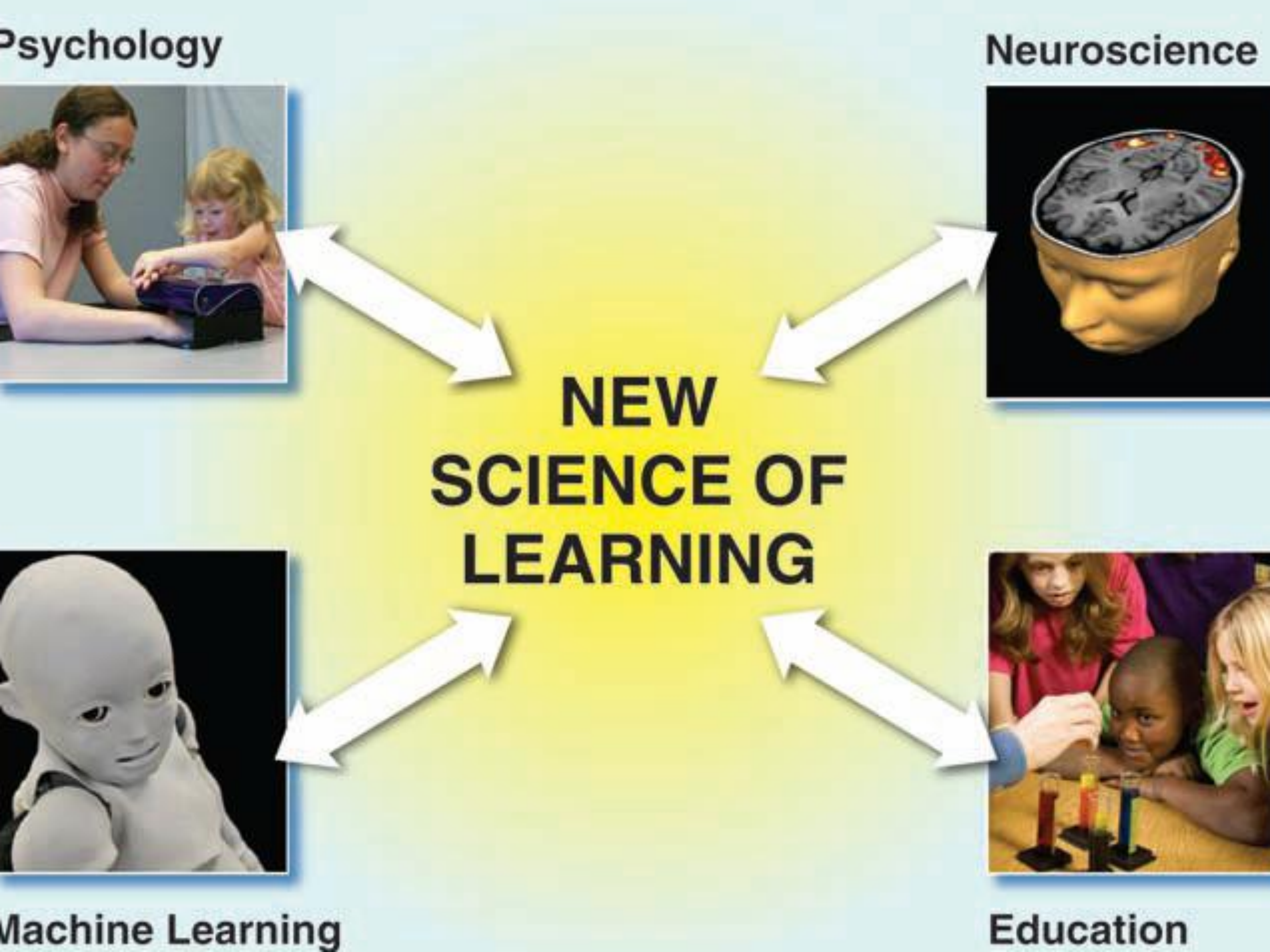
Summer, 2011

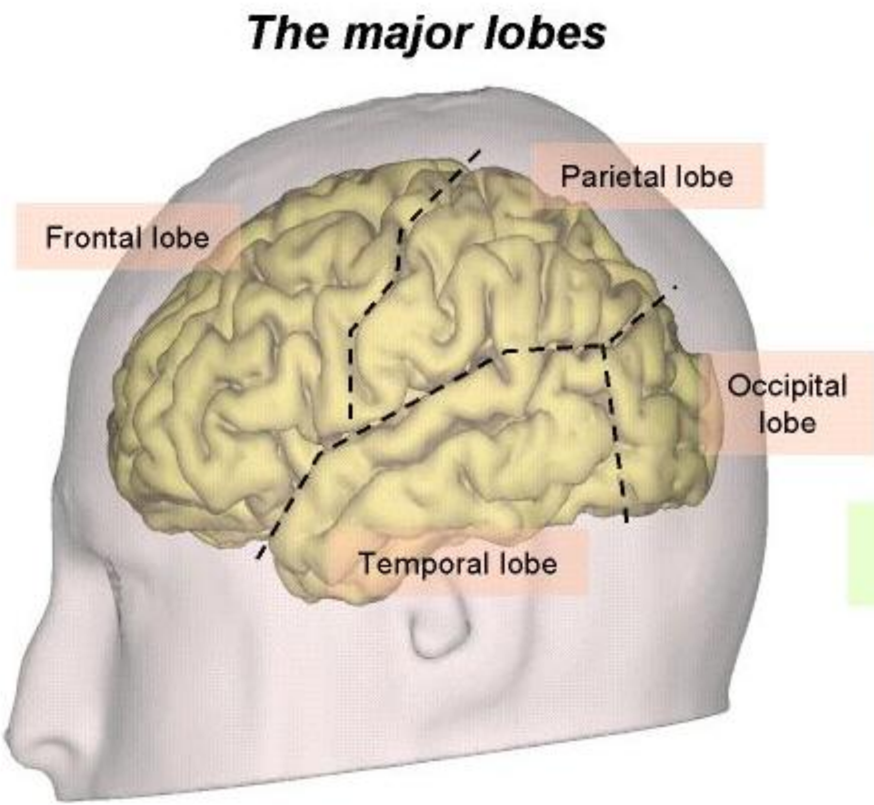
The New Science of Learning

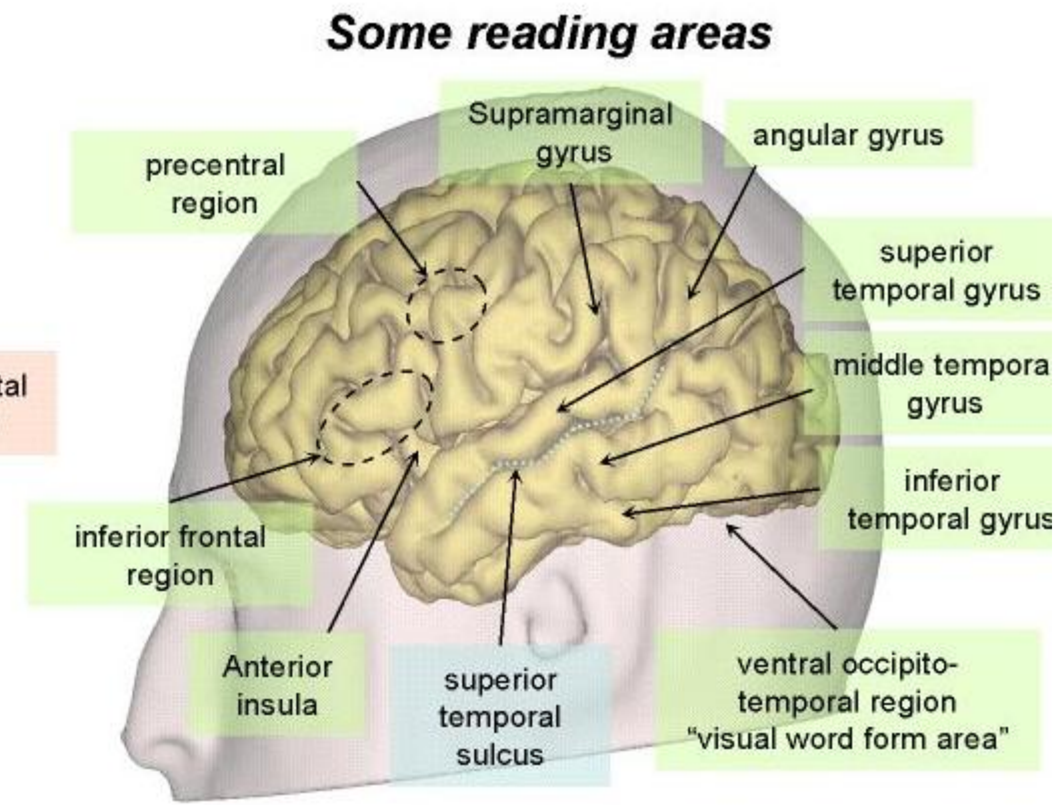
What is Neuroscience?

Brain Networks development in typical students

- **Reading and Math – early investigations**

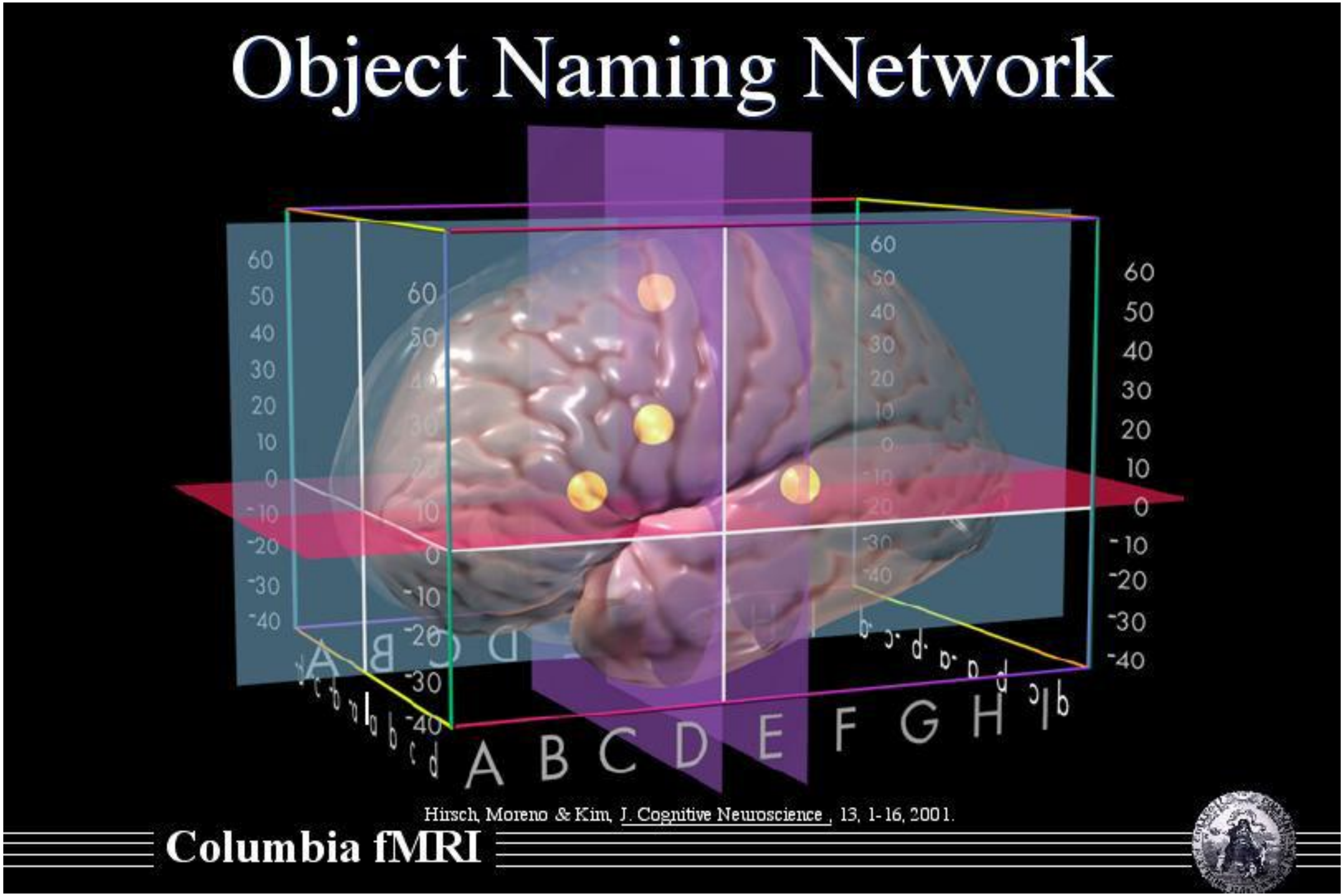

Psychology
Neuroscience
NEW
SCIENCE OF
LEARNING
Machine Learning
Education





DeHaene, 2009

Neurons that fire together wire together in networks



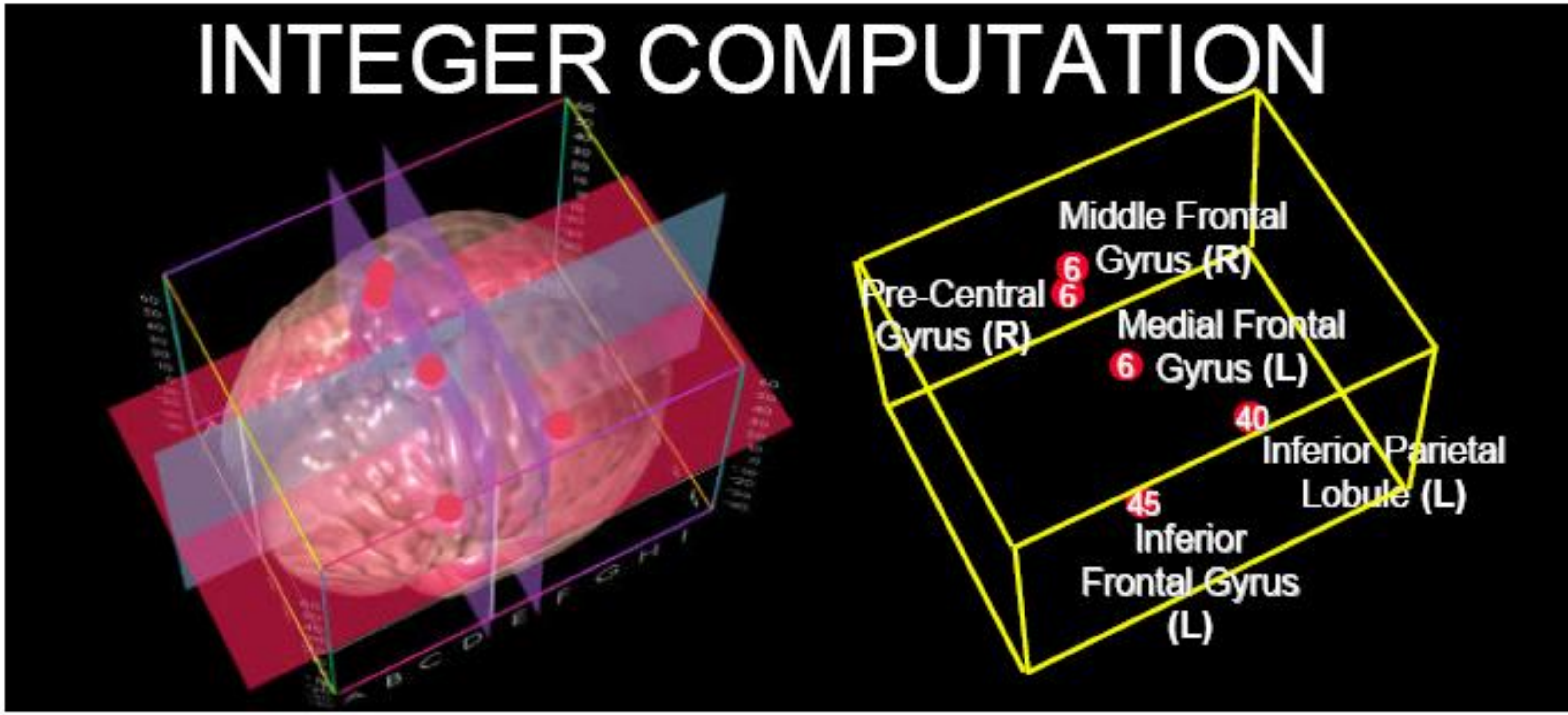


Fig 2c

Hirsch, Moreno & Kim, J. Cognitive Neuroscience, 13 (3), 389-405, 2001.

Neural correlates of arithmetic and language comprehension: A common substrate?

J.V. Baldo, N.F. Dronkers / Neuropsychologia 45 (2007) 229–235

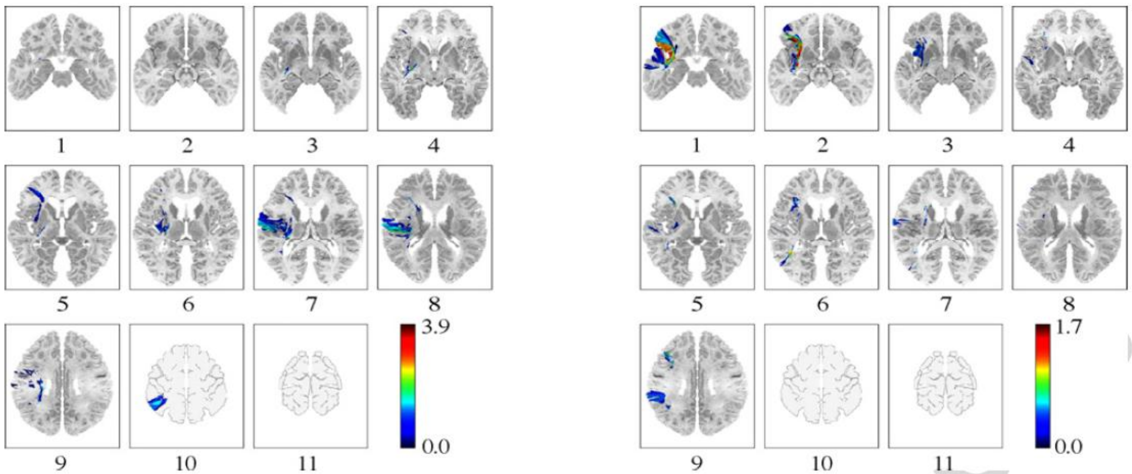


Fig. 4. VLSM subtraction maps of subtraction minus comprehension (left) and division minus comprehension (right).

In conclusion, we found behavioral and anatomical evidence consistent with the notion of partially overlapping networks subserving language comprehension and arithmetic. The extent of this overlap is likely dependent on which aspect(s) of mathematical ability is tested and the way it is evaluated. Along with previous findings, these data suggest that language is related to arithmetic ability

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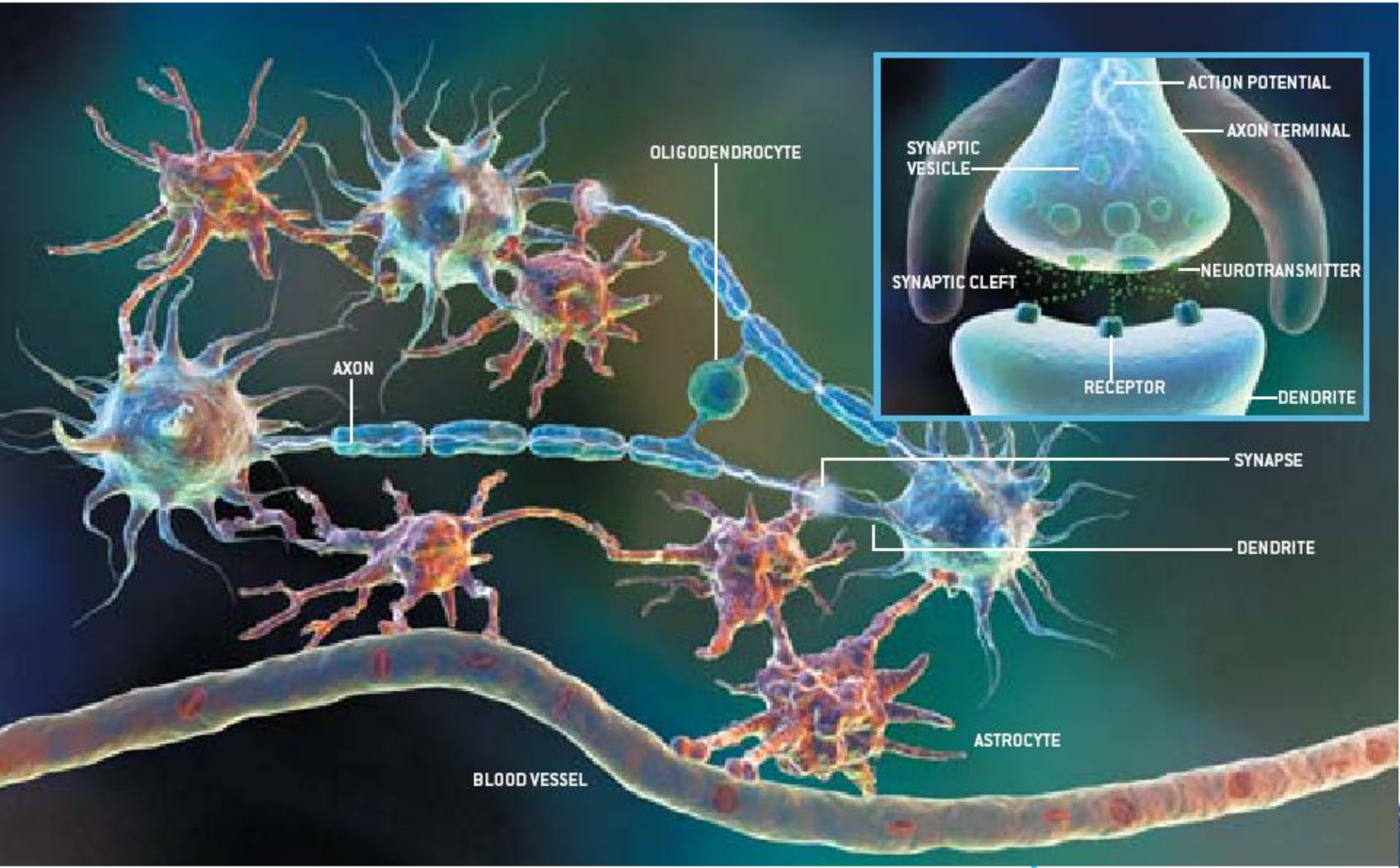
1. **What these regions do and…..**
   - **How they are connected via superhighway system**
   - **How the highways develop in early years**

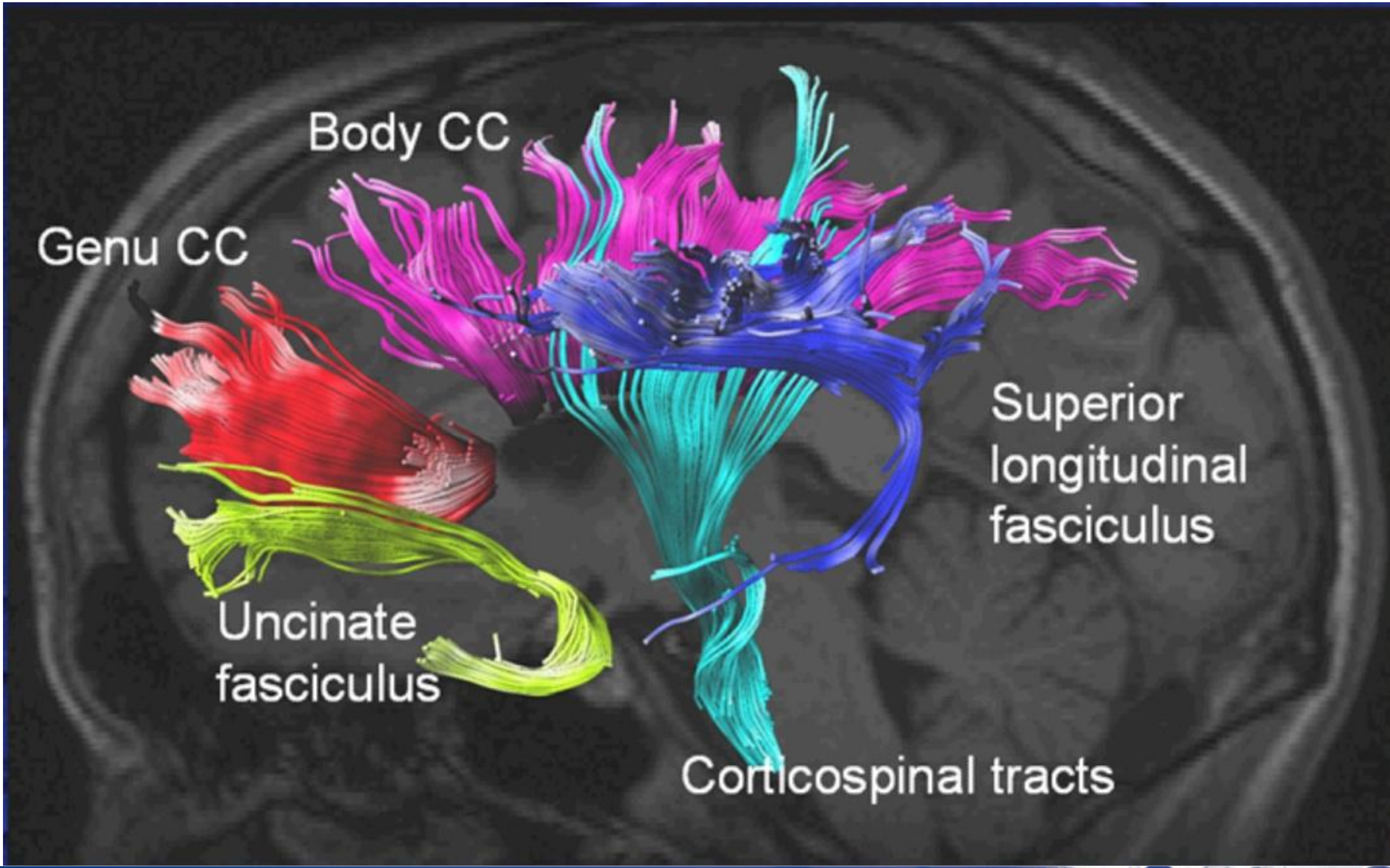
Neuronal communication system



Different dimensions of adult cortical plasticity are enabled by the behaviorally-context-dependent release of:

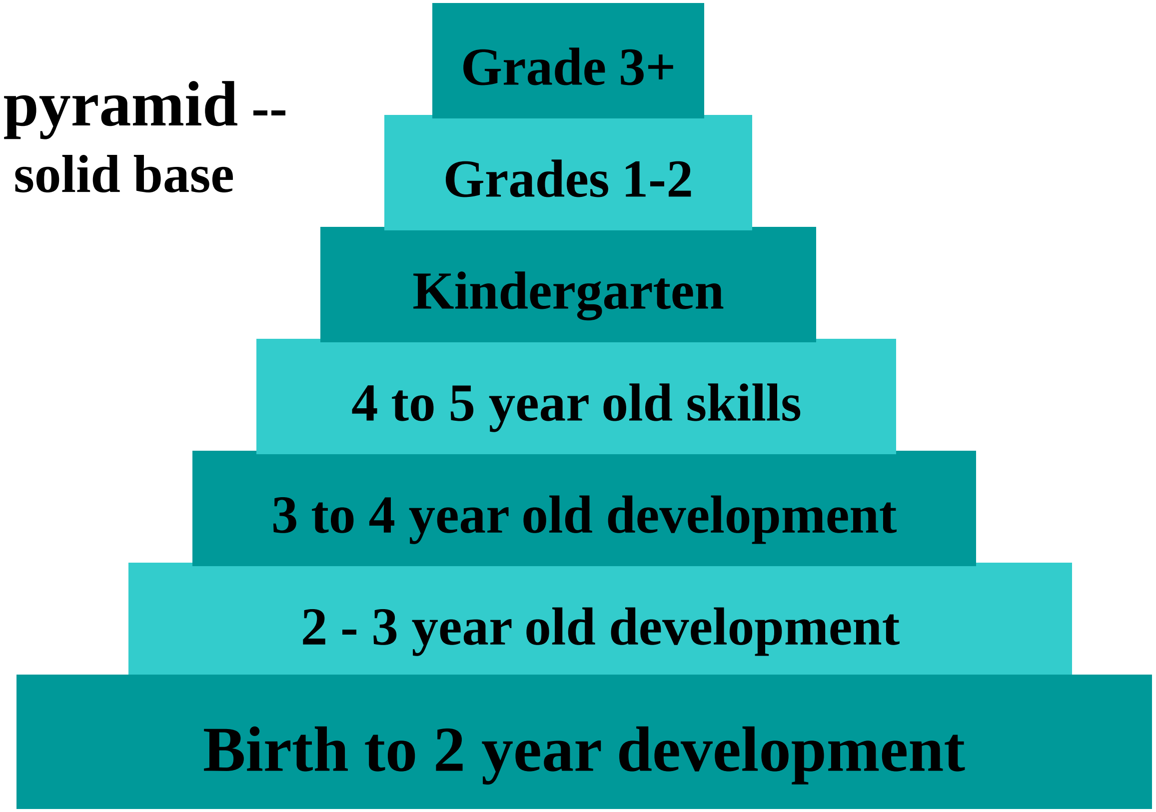
- **acetylcholine (focused attention/reward) (Kilgard, Bao)**
- **dopamine (reward, novelty) (Bao)**
- **norepinephrine (novelty) (Bollinger)**
- **serotonin (Bollinger)**
- **Adenosine 5’-triphospate (ATP) released by axons and stimulates myelination (Ishibashi)**
- **et alia**

In infants, exposure-based plasticity is relatively uniform.
In older children, learning-induced changes are complexly “nuanced” by differences in behavioral context that result in the differential release of 6 or 7 modulatory neurotransmitters.


Body CC
Genu CC
Superior longitudinal fasciculus
Uncinate fasciculus
Corticospinal tracts

How does reading become superimposed on language?

Reading development pyramid --
upper levels depend upon a solid base below



Early Language Development

- The foundation for reading
- The precursor for reading
- For some children, the bottleneck that limits success
- Children differ in language experience

Scientific Learning

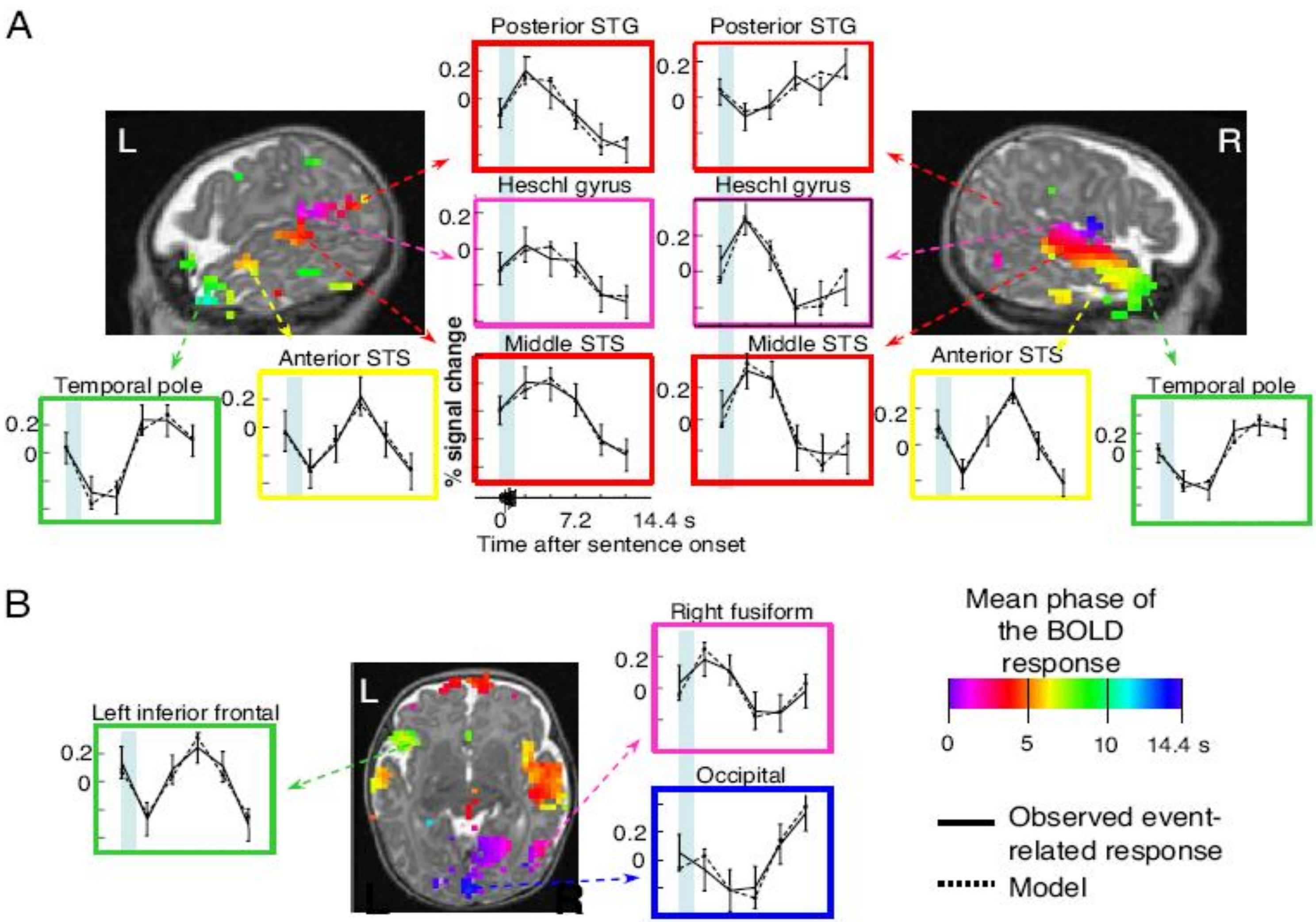
Birth to 2 years

1. Child is born - normal hearing and cognitive potential
2. Makes generalizations about sounds around him/her
   - speech sounds versus environmental sounds
   - recognizes speech sounds of own language
3. Uses own language sounds in babbling then early speech
   - full repertoire of native language phonemes by 18mo.-2 years
   - early adjectives (good, hot), verbs (see, want, go), pronouns (me,you)

10-12 months - first word

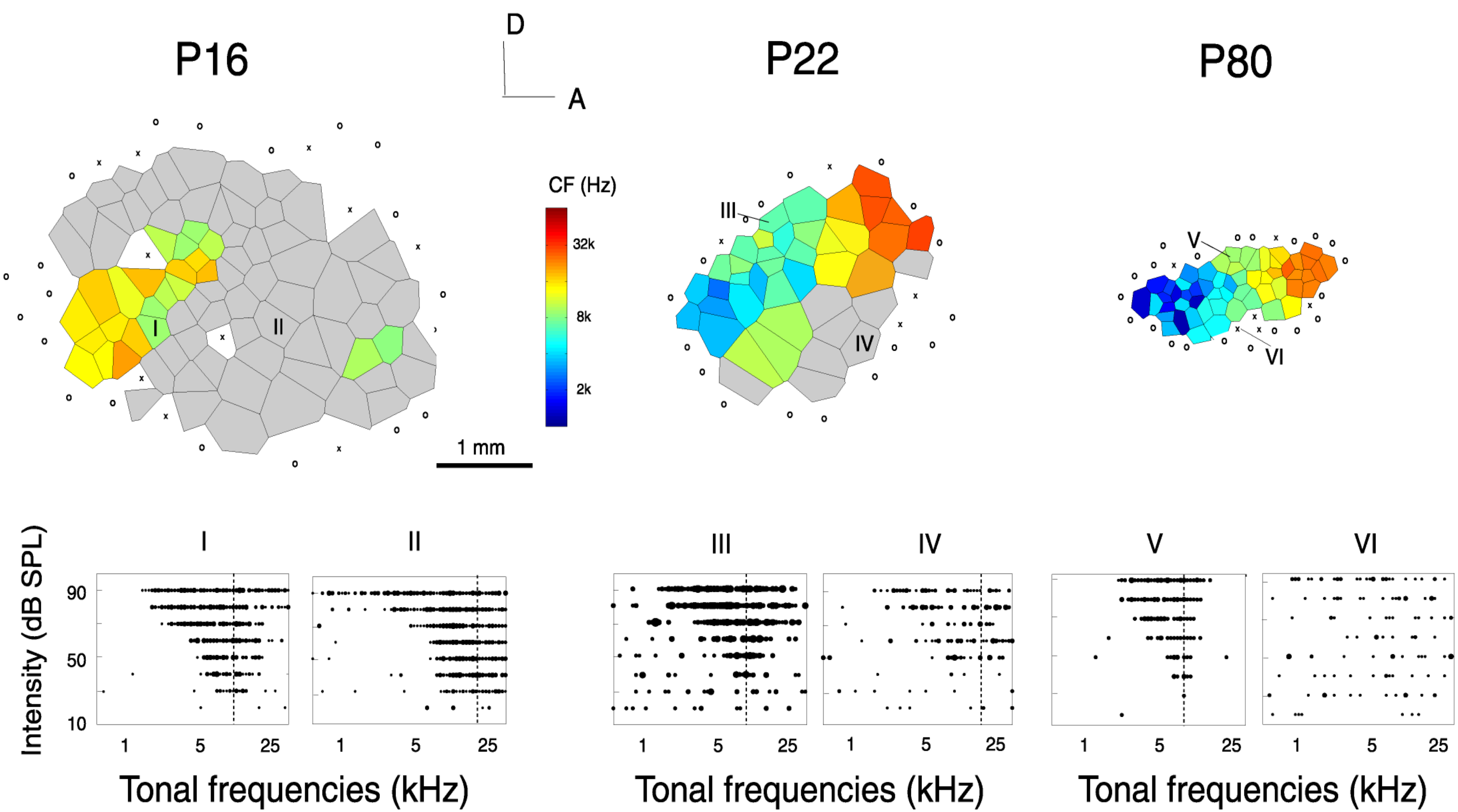
18 months - 10-20 words; 2 yr.- two word phrases; 200 words

Organization of cortical responses to spoken language in 3 m old infants.



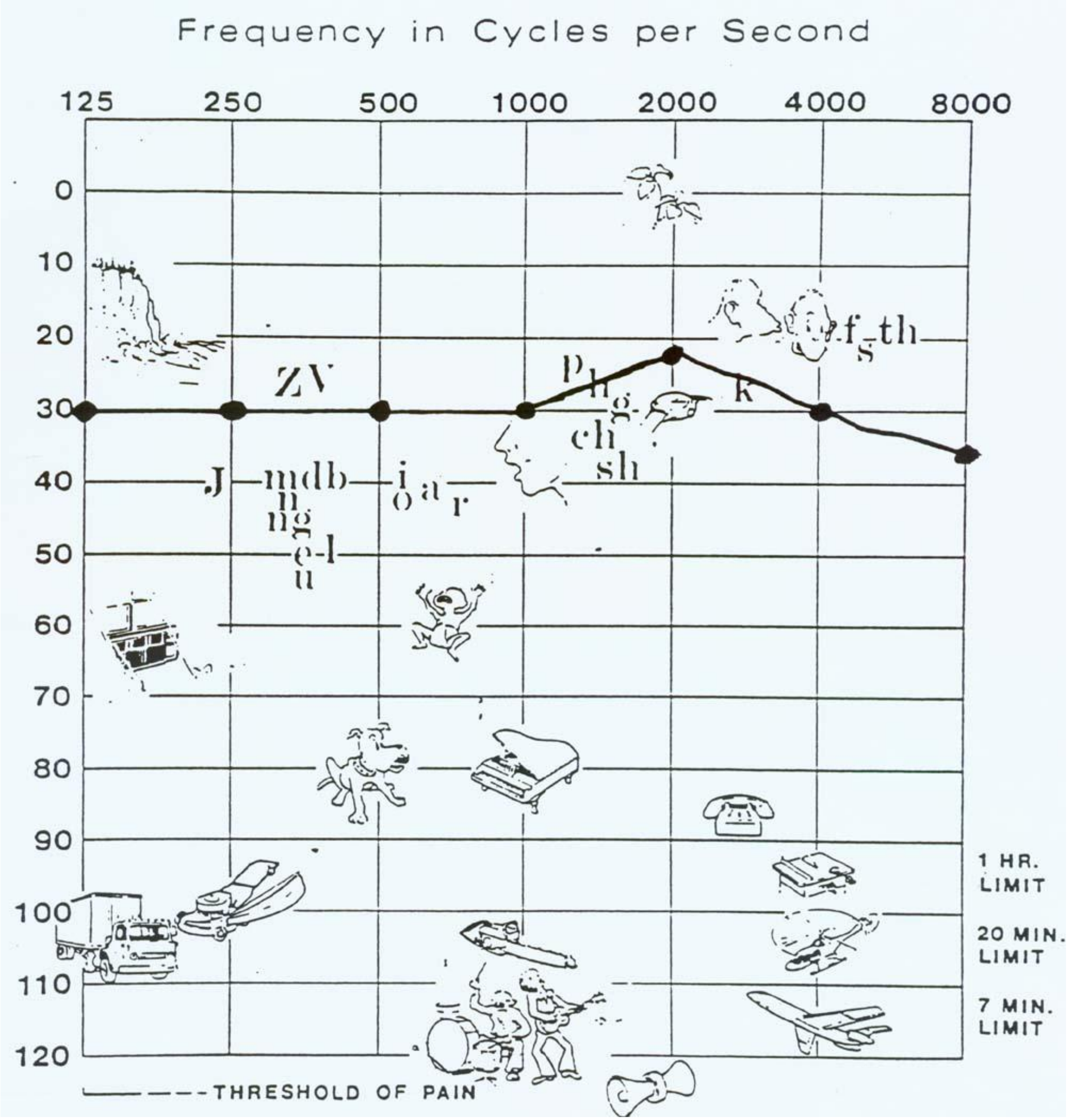
Dehaene-Lambertz, et. al, 2006

Normal development of the brain maps for hearing



Zhang, Bao & Merzenich, Nature Neuroscience, 2001

Brain maps depend on hearing the sounds



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How educators build left hemisphere hubs that support learning and the networks and make them more efficient

Structural MRI studies of language function (Fiona M. Richardson, Cathy J. Price, *Brain Struct Funct* (2009) 213:511–523)

- The relationship between vocabulary knowledge and brain structure in 47 participants ages 7 to 75 years.
- The relationship between vocabulary knowledge and posterior supramarginal grey matter was also studied in 16 teenage participants

Richardson and Price, 2009

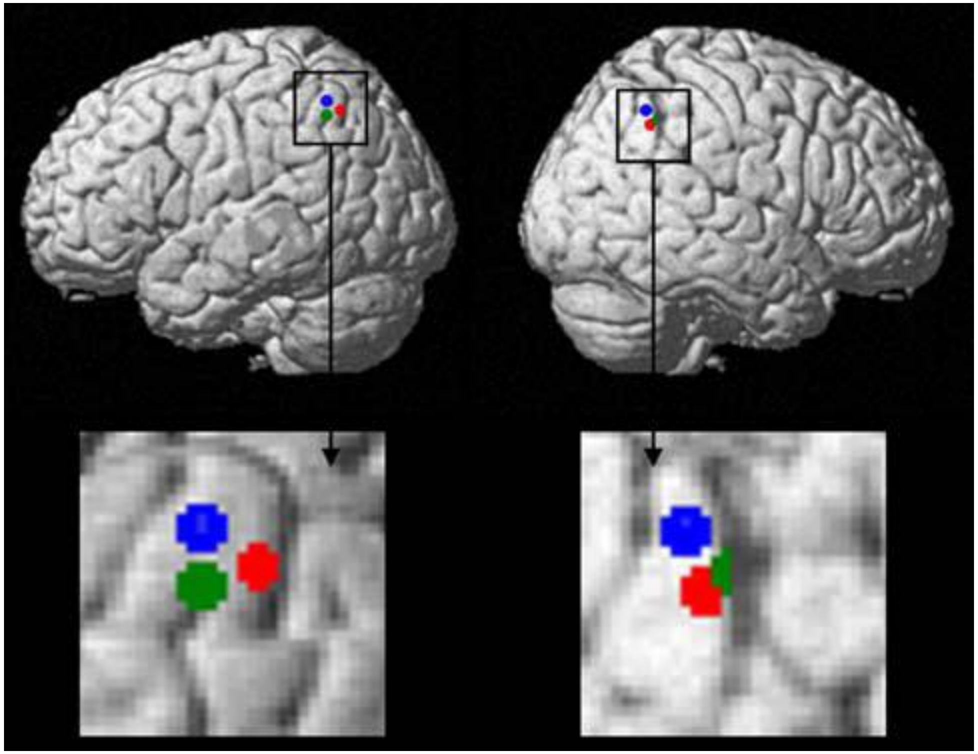
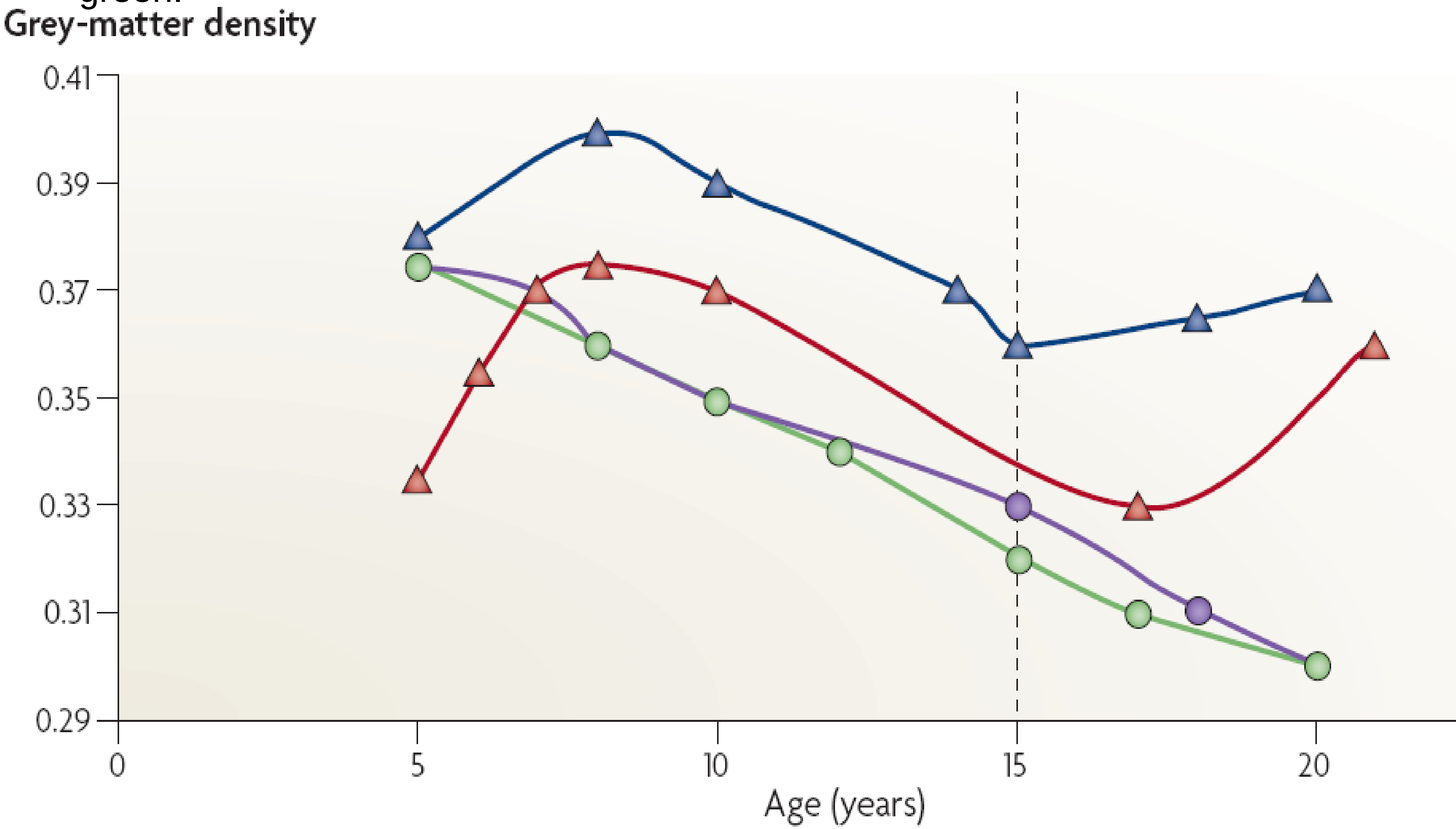


Fig. 1 Structural variance with vocabulary knowledge in the posterior supramarginal gyrus. Locations of the peak co-ordinates from the following studies: red Mechelli et al. (2004), blue Lee et al. (2007), and green Richardson et al. (2009).

The correlation of vocabulary knowledge with grey matter in the left posterior supramarginal gyrus in teenage years, but not later in life, suggests that **this region is engaged in learning more typically exploited within formal education**, e.g.learning to link new words with specific lexical equivalents.

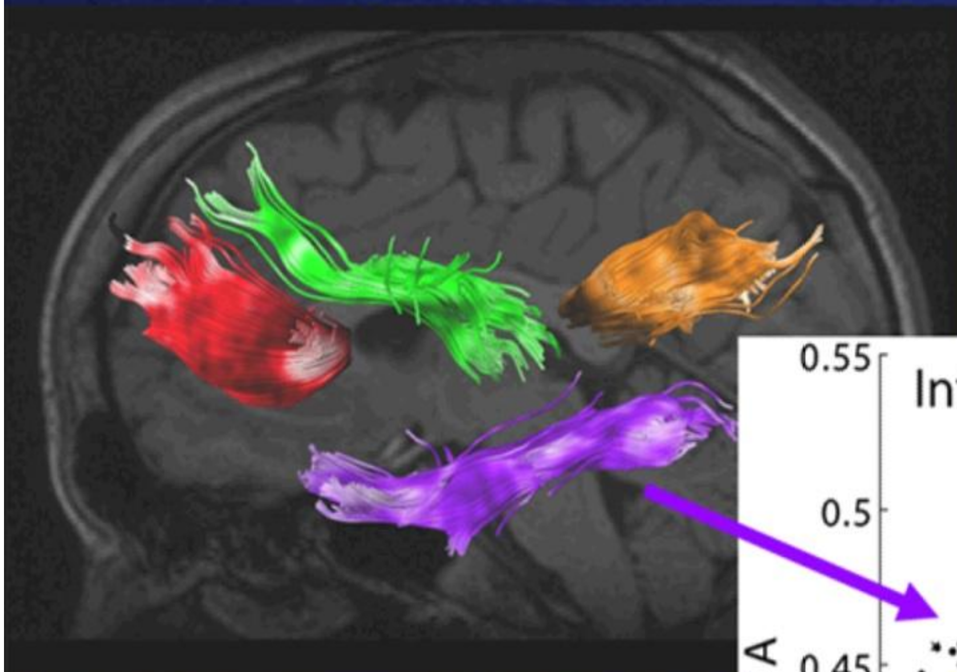
Plots of grey-matter density are based on data by Gogtay *et al.* 2004 and illustrate the local grey-matter density in the mid-dorsolateral prefrontal cortex in red, in the angular gyrus of the parietal cortex in blue, in the posterior superior temporal sulcus of the temporal cortex in purple, and in the occipital pole in green.



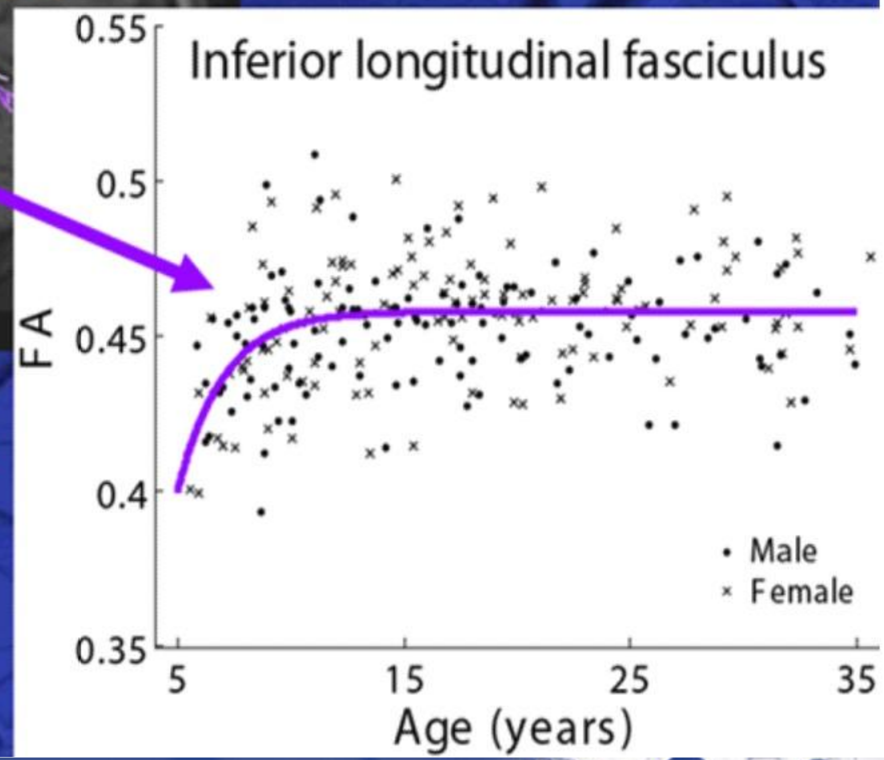
Ability to easily learn a foreign language (Richardson and Price, 2009)

- Those who were able to learn an unknown foreign language
  - showed a greater **left hemisphere** asymmetry in the parietal lobes
  - and also had **more white matter** (fiber tracts) in left hearing and language temporal lobe region
    - Affirms other research that found **increased grey matter** in the auditory cortex in those with good auditory perception
      - Also observed in musicians (Gaser and Schlaug 2003; Schneider et al. 2002)
      - as well as for those with an aptitude for learning tonal languages such as Mandarin, where pitch is particularly important for distinguishing between words (Wong et al. 2008)

Rapidly Developing Tracts



Reach 90% of maximum FA before age 11 years



Inferior longitudinal fasciculus
Splenium corpus callosum
Genu corpus callosum
Superior fronto-occipital fas.

Turken and Dronkers (2010) in press – White Matter tracts underlying auditory speech processing

FISN 23

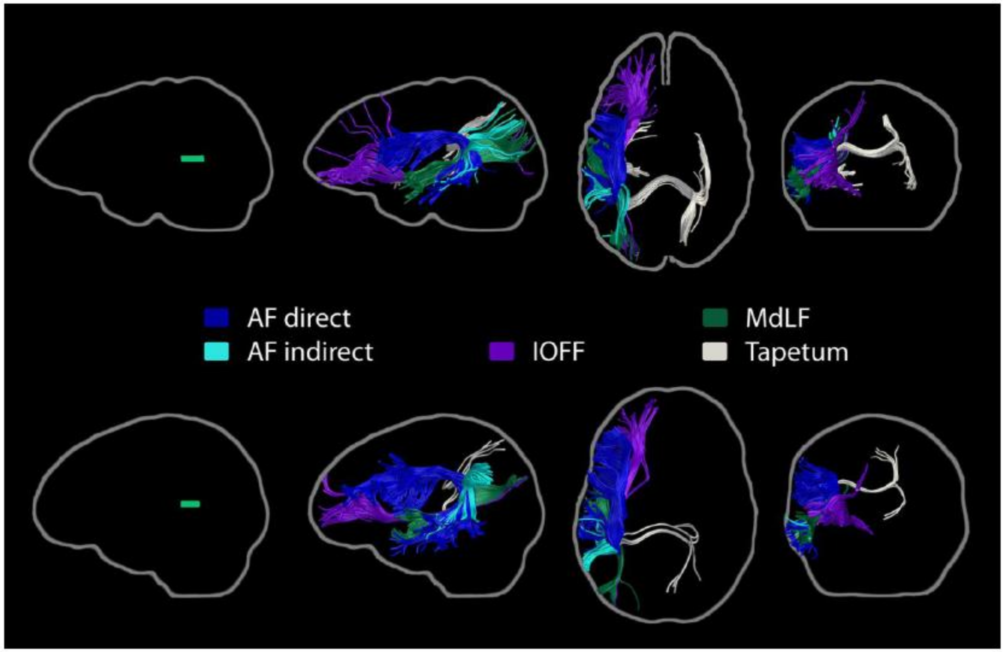


Figure 13. Fiber pathways passing through the white matter underlying the superior temporal sulcus. Five different fiber bundles were found to contribute fibers to this small white matter region (left, green). Direct and indirect segments of the arcuate fasciculus, the inferior occipito-frontal fasciculus, the middle longitudinal fasciculus and the tapetum are shown for the two subjects chosen as exemplars.

Turken and Dronkers (2010 in press) speech, fluency and grammar pathways

FISN 18

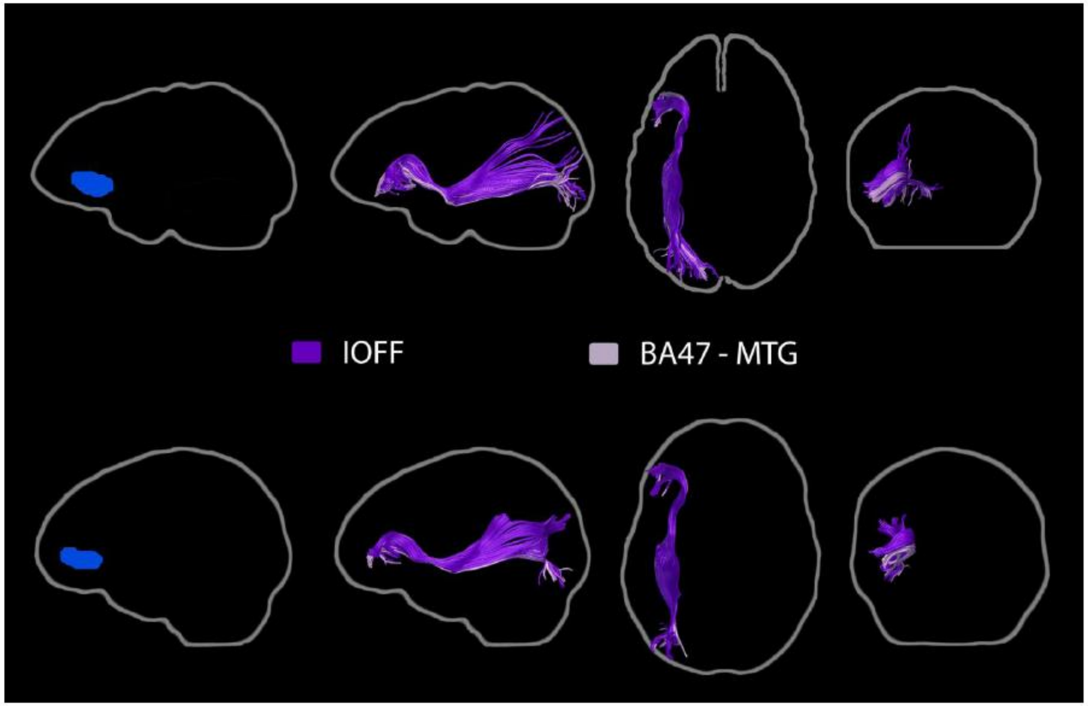


Figure 8. Pathways associated with the BA47 ROI (left, blue). Streamline tractography results from two subjects are presented as exemplars. The inferior occipito-frontal fasciculus as well as a group of IOFF fibers associated with the posterior MTG ROI were identified.

Decreased Interhemispheric Functional Connectivity in Autism

- Jeffrey S. Anderson, T. Jason Druzgal, Alyson Froehlich, Molly B. DuBray, Nicholas Lange, Andrew L. Alexander, Tracy Abildskov, Jared A. Nielsen, Annahir N. Cariello, Jason R. Cooperrider, Erin D. Bigler and Janet E. Lainhart

- ***Cerebral Cortex* Advance Access published October 12, 2010**

- Examined resting-state blood oxygen level--dependent interhemispheric correlation in 53 males with high functioning autism and 39 typically developing males from late childhood through early adulthood

Anderson, et al., 2010

- found significantly reduced interhemispheric correlation specific to regions with functional relevance to autism:
  - sensorimotor cortex,
  - anterior insula,
  - fusiform gyrus,
  - superior temporal gyrus, and
  - superior parietal lobule
- Observed interhemispheric connectivity differences were better explained by diagnosis of autism than by potentially confounding neuropsychological metrics of language, IQ, or handedness.

Distortions and disconnections: disrupted brain connectivity in autism (Wass, 2011)

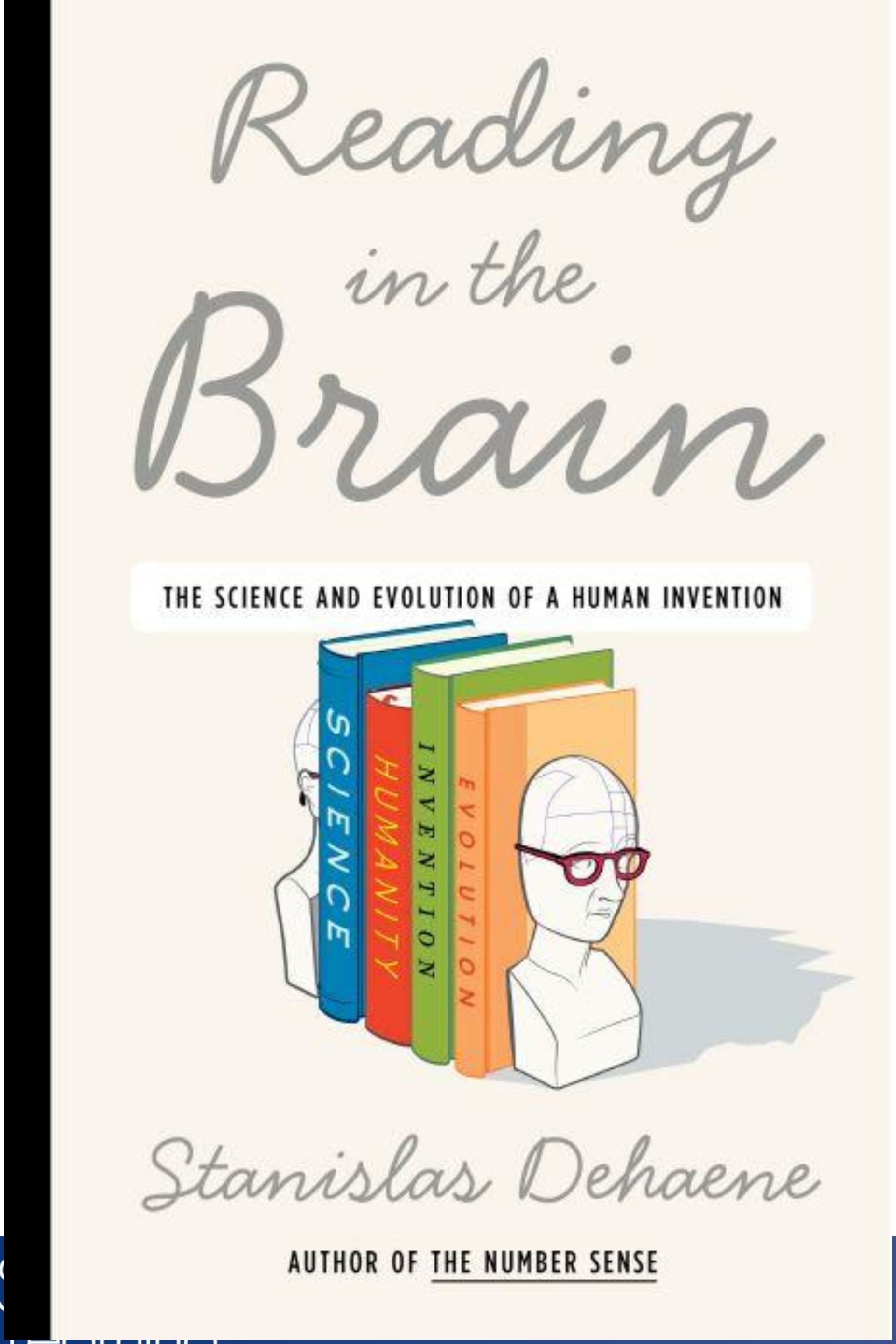
- Point to evidence that there is local over-connectivity
  - Perhaps leading to repetitive behaviors and savant characteristics
- Long Distance underconnectivity
  - Leading to problems with long fiber track networks for:
    - Language and problem solving
    - MNS and TOM (see tomorrow’s discussion)

Wass, 2011

- Review DTI studies that reveal inter-hemispheric structural under-connectivity in mature subjects with ASD
  - With younger subjects the results are more mixed
- Also evidence showing disruptions to and from frontal and temporal cortices may be most heavily disrupted in ASD
  - This is consistent with early relatively intact development becoming progressively more disrupted during the first two years of life

Wass, 2011

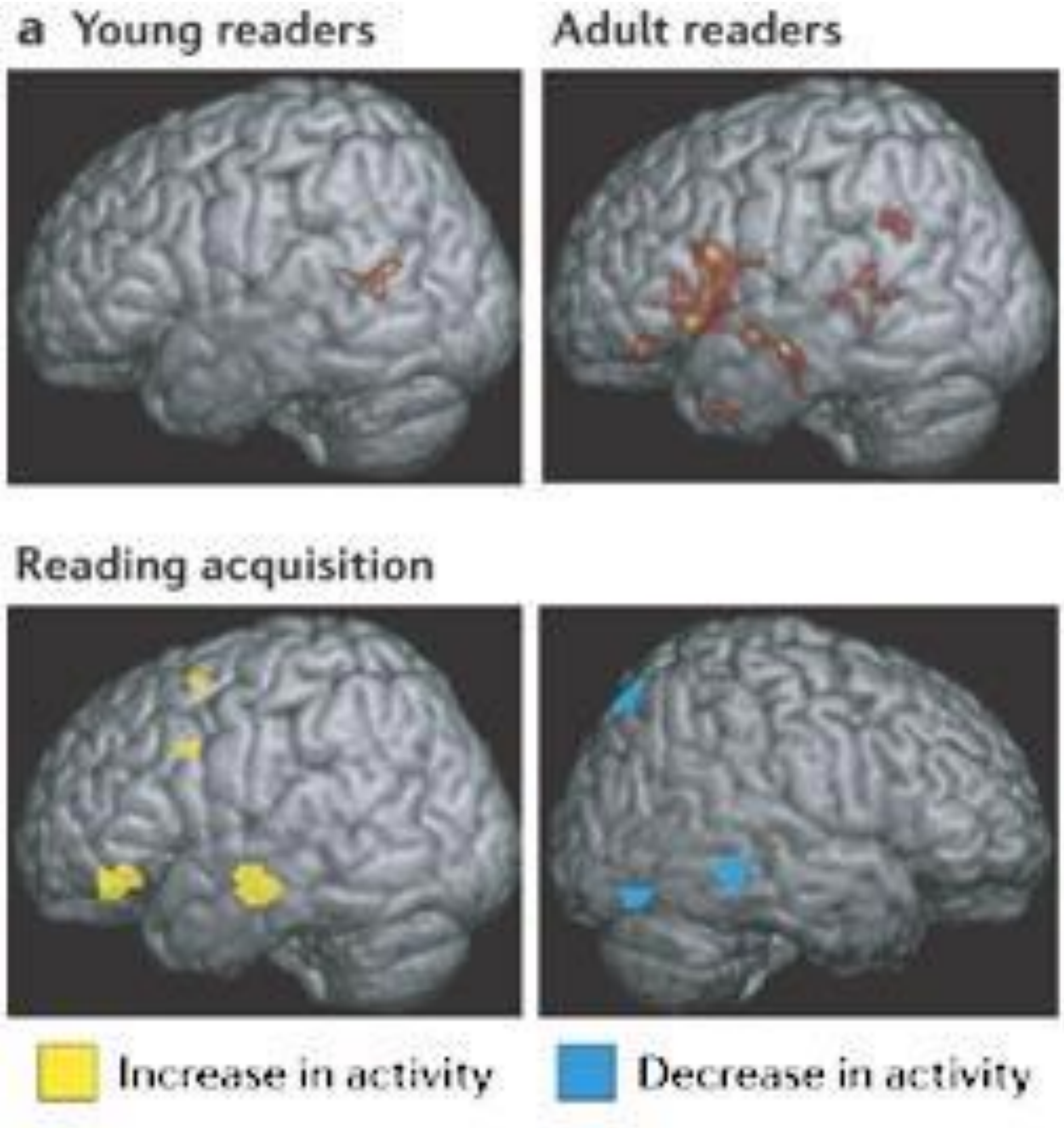
- fMRI and EEG studies show evidence of functional over-connectivity but with this regard DTI is more mixed
  - Strongest evidence of local over-connectivity comes from the micro-level from a small number of post-mortem studies
- Tantalizing evidence that increased short-range connectivity and decreased long-range may resemble that found in immature vs. mature typically developing children
- ASD may be partially due to failure to undergo typical developmental process
- SO – is this the primary pathogeneis or does it develop over time?



So what about reading?

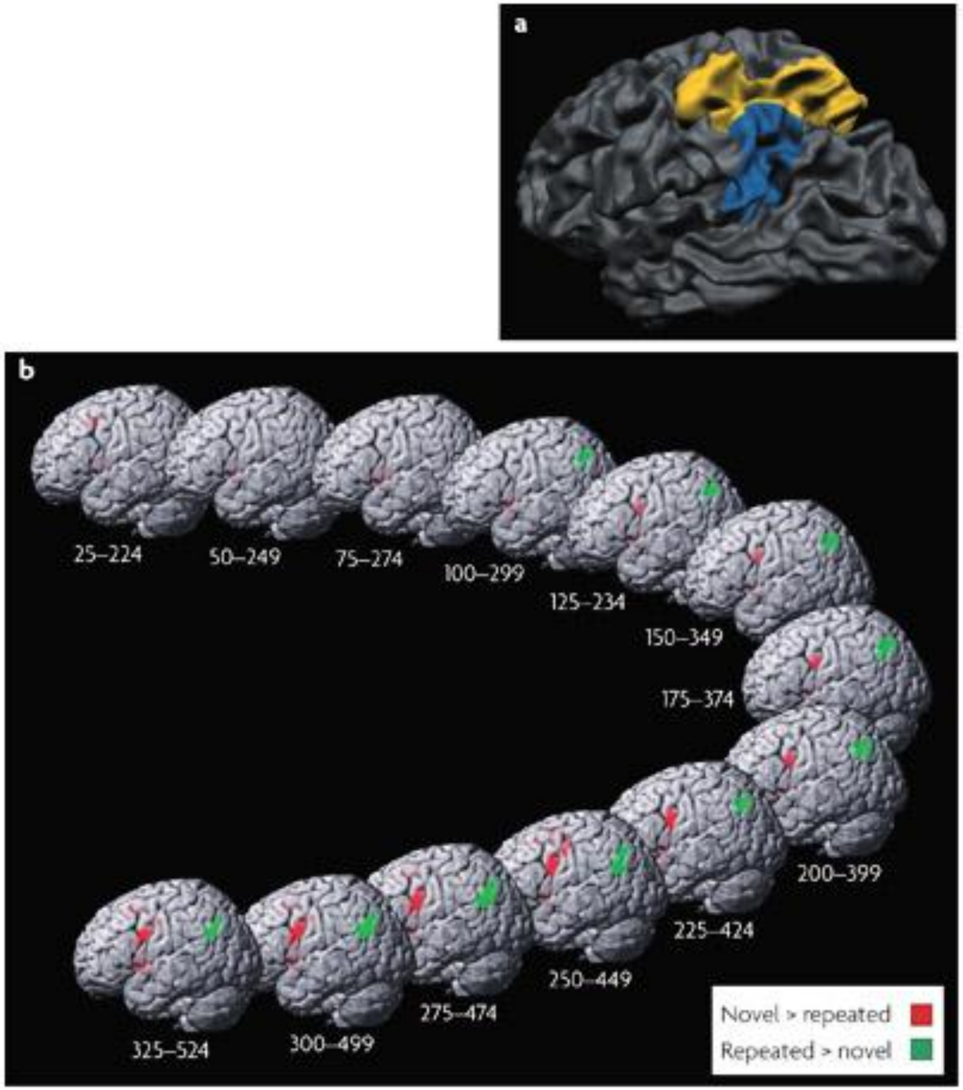
Viking Press

December 2009



Turkeltaub et al *Nature Neuroscience* 2003

nature REVIEWS NEUROSCIENCE



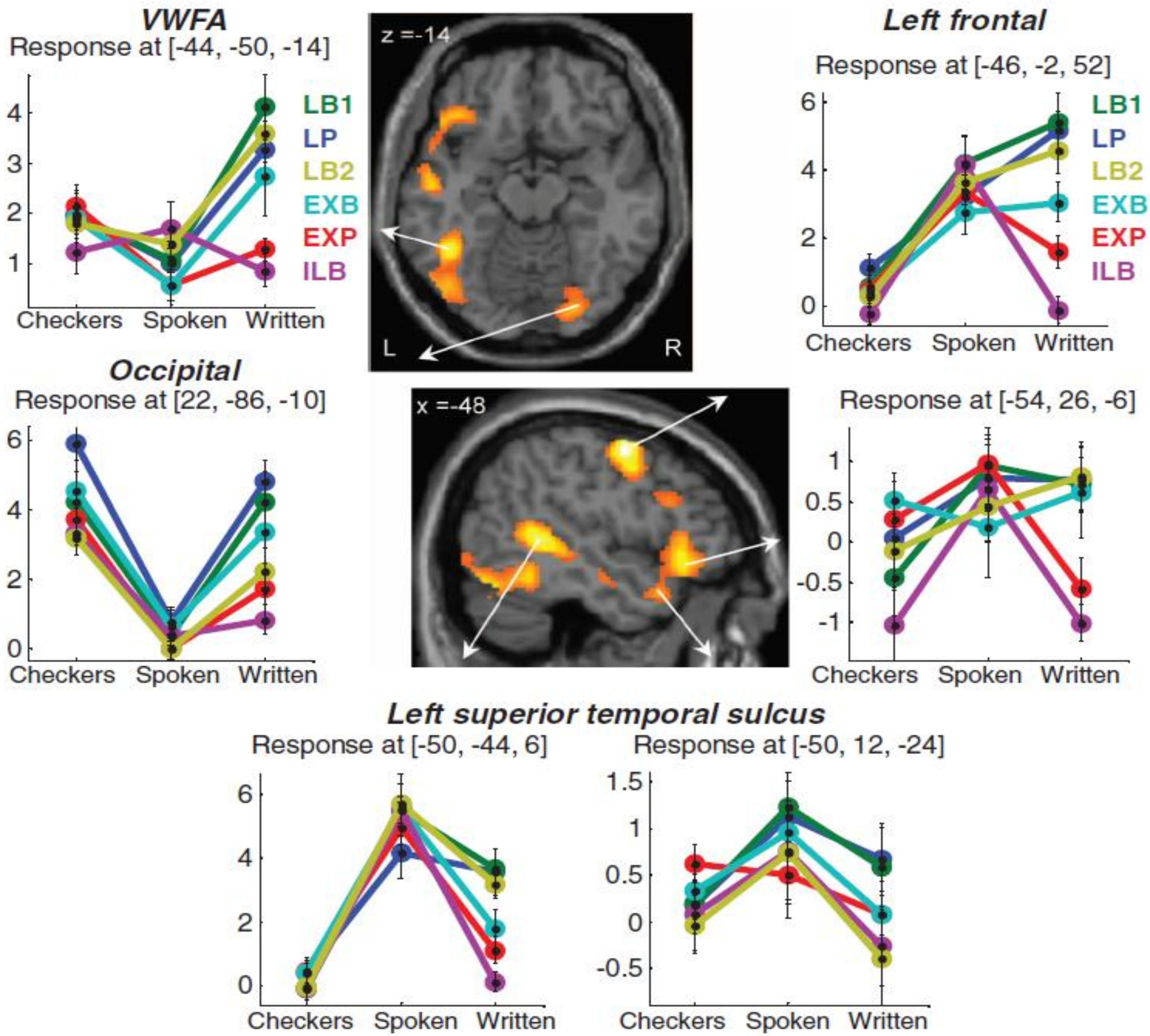
Nature Reviews | Neuroscience

a | Training for arithmetic problems leads to decreasing engagement of the inferior parietal cortex (shown in yellow) and increasing recruitment of the angular gyrus (shown in blue).

b | a moving time window of 200 scans and reveals that there are significant changes in activity of the angular gyrus (shown in green) after only approximately 8 repetitions of a problem

How Learning to Read Changes the Cortical Networks for Vision and Language

Science ***330, 1359 (2010);***
Stanislas Dehaene*, et al.*


VWFA
Response at [-44, -50, -14]
Checkers Spoken Written
LB1
LP
LB2
EXB
EXP
ILB
z =-14
L
R
Left frontal
Response at [-46, -2, 52]
Occipital
Response at [22, -86, -10]
x =-48
Response at [-54, 26, -6]
Left superior temporal sulcus
Response at [-50, -44, 6]
Response at [-50, 12, -24]

Literacy enhances brain responses in three ways (DeHaene, 2010)

- Boosts organization of the visual cortex
- Allows practically the entire left hemisphere spoken language network to be activated by written sentences
- Refines spoken language processing by enhancing the phonological region

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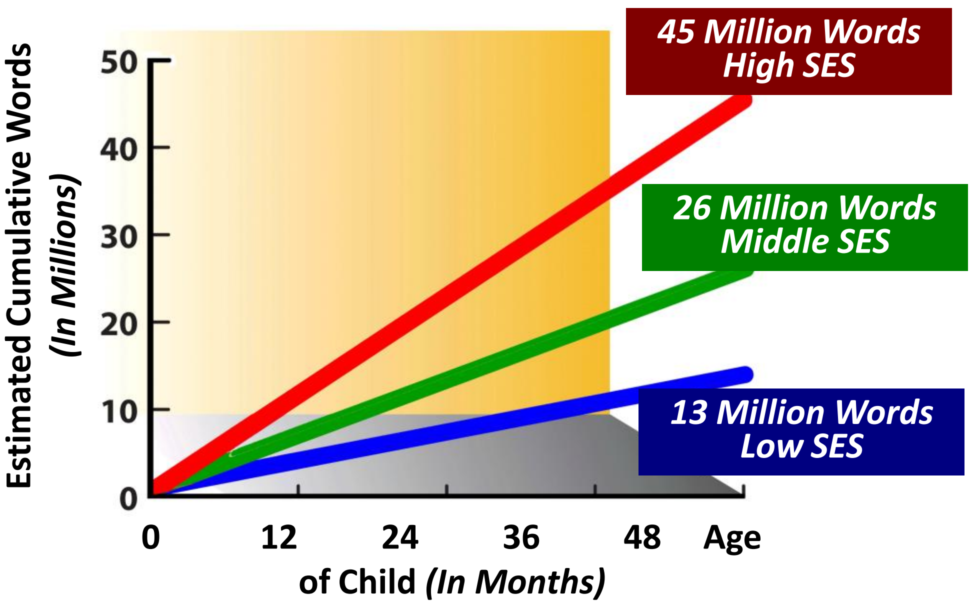
Reasons some children may enter school with good learning potential

…….but a brain that is not yet ready to read

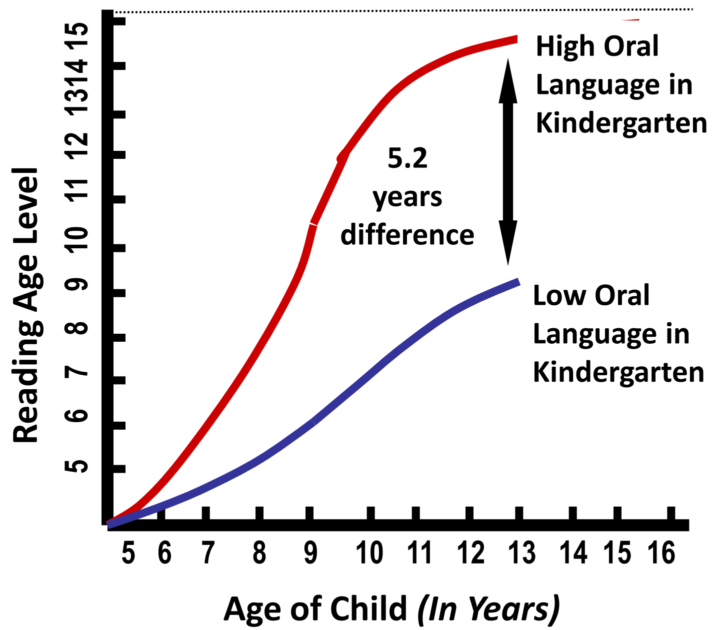
Language Exposure and SES

Cumulative Effects of Language Experience



(Hart and Risley, 1995)

Effects of Low Language Development on Reading



(Loban, 1967; Hirsch, 1996)

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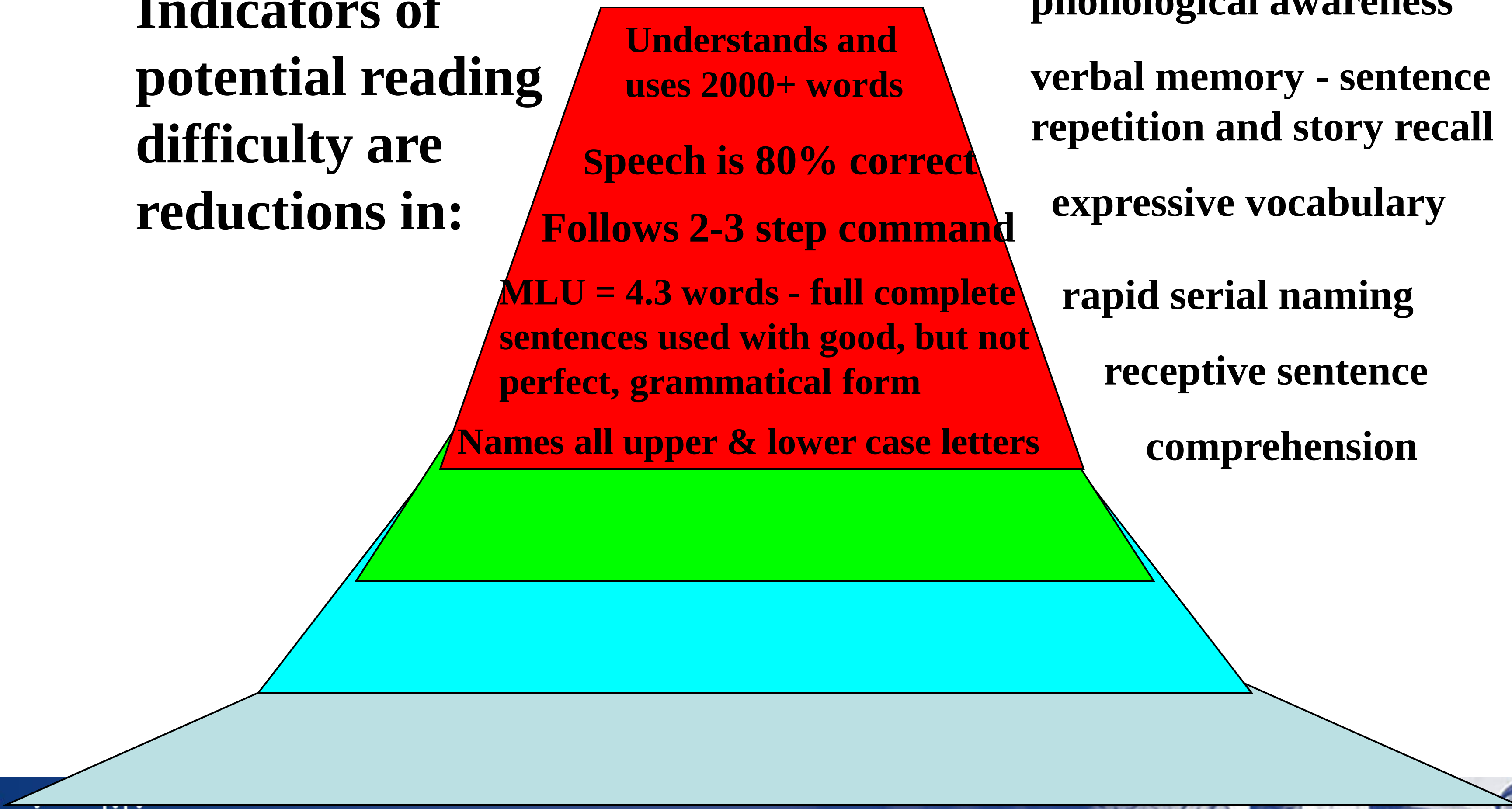
Kindergarten

Indicators of potential reading difficulty are reductions in:



- phonological awareness
- verbal memory - sentence repetition and story recall
- expressive vocabulary
- rapid serial naming
- receptive sentence
- comprehension

ELL

- Need to build the ability to perceive internal detail to words
- Phonics instruction is a much less transparent in English than many other languages
  - Much easier to learn to read Spanish than English (DeHaene, 2009)

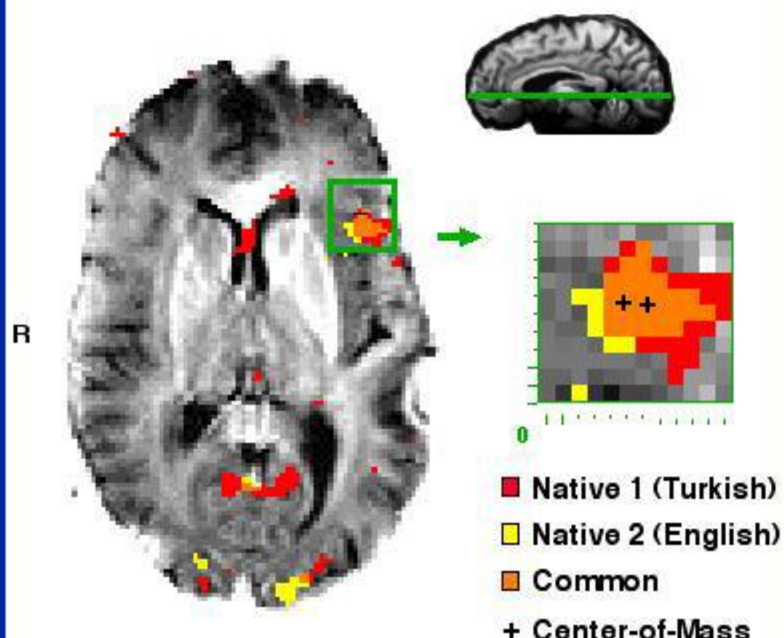
ELL prevalence

- **According to the 2000 census, nearly one-third of children ages 5 years and older speak Spanish at home. Add the under-5 population and the percentage is even higher. Due to continued immigration and globalism, the bilingual population will continue to grow in Texas.**
- **5-8% of these children exhibit a speech-language problem in their native language which will require remediation in addition to bilingual education**

Second Language Learning

- Affects the way the brain is organized for language
- Differs depending upon when the second language is learned
- After the critical period requires the same developmental criteria as the first language

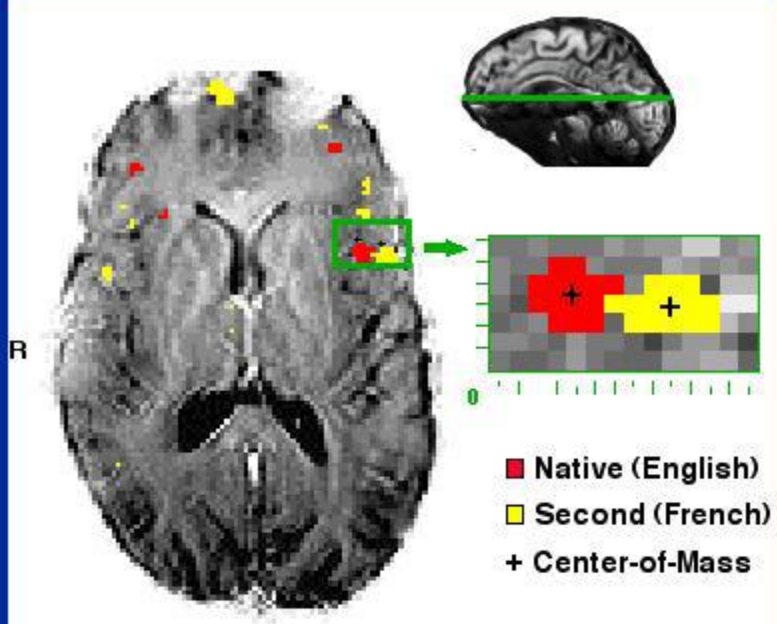
Learning a second language during the critical period



From Kim, et al, Nature, 388, 171-174, 1997

Columbia fMRI

Learning a second language after the critical period



From Kim, et al, Nature, 388, 171-174, 1997

Columbia fMRI

Oral Language

- Over 80% of classroom instruction is presented through talking

- Language processing, primarily at the level of phonology, is the primary cause of reading and spelling problems