Why is learning language so easy for some children?

- How does the brain organize for language?
- How do brain cells communicate with each other?
- Why “quick” learners are often “easy talkers” the role of white matter pathways
- What does listening have to do with it?
Neuronal communication system

Neurons that fire together wire together in networks
Neuroscience Updates as of January 2017

- Brains build like schools do: they reorganize as they expand
- Brain areas we used to consider emotional, such as the regions of the "limbic system," are now known to be major hubs for general communication throughout the brain – so managing motivation and reinforcement is essential – that’s what drives the hubs to form

Nodes, edges and modules closeup


• Nodes (orange dots) are connected by short and long range edges (light blue lines) within modules (in green dotted circle).
• Connections between nodes, for example node a and node b, can have a short path length (solid yellow arrow) or a long length (dotted yellow arrow).
• Rich club nodes (red glowing dots) are connected across modules with strong (solid dark blue lines) and weak (dotted dark blue lines) long-range edges. Adapted from

Brain Building Processes

• 1. Proliferation – neighborhood and suburb building
  – A. Synaptogenesis (neighborhoods connected by yards) and B. axon development (access roads)
• 2. Pruning – clearing out the trees, unpaved roads, old unused houses, and other barriers to development
  – Competitive elimination

Zhang, Bao & Merzenich, Nature Neuroscience, 2001
Fig. S6. Spatial organization of responses in STG
(A) Location of electrodes in one subject color coded by cluster membership in Fig. 2C shows a dispersed pattern
(B) Correlation values of electrode PSIs plotted against their distance shows a small but significant relation between similarity of PSIs with distance between electrodes.

And Proliferation leads to Axons
Development

The building starts just before birth but is most profound before 5
T.V. doesn’t help

Early Language Development

• The foundation for reading
• The precursor for reading
• For some children, the bottleneck that limits success
• Children differ in language experience
The critical period for learning language

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)

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

Dehaene-Lambertz, et. al, 2006
The development and role of phonological working memory

Phonological Working Memory for Words and Nonwords in Cerebral Cortex


- The present results delineate a cortical network consisting of three core areas—STG, IFG, and SMA—that support phonological working memory.

This network of brain areas closely parallels those previously shown to support core phonological processing, models of phonological working memory as an emergent property of the language system.

Normal Development of the Brain Maps for Hearing

Categorical Perception

SYNTHETIC DATA

Chang, et al, 2010
Infants exposed to TV or audio only show no difference in acquisition of the new sound system compared with children never exposed. Infants exposed through social interaction of the same duration and intensity acquire the new phonology.

**BUT AFTER THE CRITICAL PERIOD DIRECT INSTRUCTION IS NECESSARY**
Two to three years - early phonological awareness

1. Word play - “Higglety, pigglety, pop”; “Hickory, Dickory, Dock”
2. Rhymes and alliterative stories
   - Little Miss Muffett
   - Peter Piper picked a peck of pickled peppers
3. Delayed expressive syntax and phonology predict poor reading three years later

Kindergarten

Indicators of potential reading difficulty are reductions in:
- Understands and uses 2000+ words
- Speech is 80% correct
- Follows 2-3 step commands
- MLU = 4.3 words - full complex sentences used with good, but not perfect, grammatical form
- Names all upper & lower case letters
- Phonological awareness
- Verbal memory - sentence repetition and story recall
- Expressive vocabulary
- Rapid serial naming
- Receptive sentence comprehension

Brain maps depend on hearing the sounds
Over time consolidation leads to reorganization for higher level processes

- 3. Consolidation – hubs form that interconnect high volume areas for:
  - Easy, rapid access
  - Dominant modes of transportation (subway systems, airlines, interstate highway access points)

THE READING NETWORK
DeHaene, et al. 2015

So, the hubs build based on volume (think use – thousands of repetitions)

- And are essential for much cognition besides emotion, such as:
  - language,
  - stress,
  - and even the coordination of the five senses into a cohesive experience.

- And, these brain regions have another intriguing property:
  - *When you work them you tend to feel*
    - tired,
    - stymied,
    - frustrated

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
So what about reading?

Viking Press
December 2009

English Language Learners

- Need to build the ability to perceive internal detail to words
- Phonics instruction is much less transparent in English than many other languages
  - Much easier to learn to read Spanish than English (DeHaene, 2009)
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
Old Paradigm:
Brains Stay the Same; Kids Stay the Same

New Understanding: Brains can and do change everyday. But if the experiences stay the same, so will the brain! We can change things

Thousands of Schools Prove...

- Efficient: On average, learners gain 1 – 2 grade levels in 8 – 12 weeks
- Effective: Over 220 research studies on all types of learners
- Enduring: Over 10 longitudinal studies proving gains continue after use

Language Exposure and SES

(Hart and Risley, 1995)

(Loban, 1967; Hirsch, 1996)
“Family Poverty Affects the Rate of Human Infant Brain Growth”*

![Graph showing brain development over time]

*Jamie L. Hanson et al., in *PLOS One*, Vol. 8, No. 12, Article No. e80954; December 11, 2013

So... SES does not affect intelligence or ability to learn in general

• Rather SES affects those types of learning important for academic success
• But, why????
Damage to health and well-being

• Extreme exposure to toxic stress changes the stress response system
  – Responds at lower thresholds to events that might not be stressful to others,
  – Activates more frequently and for longer periods than is necessary, like revving a car engine for hours every day.

What can a parent do?

• Talk, talk, talk
  – The more you talk to your child and around your child the better
  – Play Peek-a-boo
  – Read (sing, tell) nursery rhymes
• Play, play, play
  – Balls and dolls – for interaction
  – Cars and trains – for prepositions
What can Ed Tech Provide

- Phonological discrimination training
- Phonological Memory Training
- Language Training (Syntax, vocabulary)
- In an intensive – personalized instruction format

English Phonemic Cortical Representation

A) Proficient English

B) Auditory Processing Disorders or English Language Learners

Training Phoneme Examples

A) Early Emphasized and Stretched

B) Late Natural Speech
Attentional vs. Memory or Auditory Processing Problems

- Poor listener or tunes out (could be an auditory processing problem)
- Frequently asks – Huh? or What? when given instructions – working memory
- Looks around to see what others are doing when teacher provides instructions – working memory or APD
- Fidgets, impulsive, intrusive, yells out answers, lack of self control -- ADHD

And so, how does phonological memory and language intervention effect left temporal and frontal areas? (DeHaene, pg. 260)?

Difference before and after training
Brain Fitness: Word List Challenge

Now write down as many words as you can recall. You have one minute.

Working memory training improves reading processes in typically developing children

Sandra V. Loosli
Martin Buschkuehl
Walter J. Perrig
Susanne M. Jaeggi
Volume 18, Issue 1, 2012

Why attention is different in the classroom than in sports – maturation linked to cognitive control

• Physical Education vs. Classroom attention
  – Teams sports require global attention to many details at a time
  – Classroom attention requires selective attention to a specific input (teacher or written lesson) with the ability to ignore distractions
Attention – maturation allows for changing from global to focused

Spelling

• English is a non-transparent language
  – There are many alternate spellings for the same sounds
  • George Bernard Shaw said we could spell “fish” as phoeti
    – ‘f’ sound as ph as in “phone”
    – ‘i’ sound as oe as in “Phoebe”
    – ‘sh’ sound as ti in “Nation”
Spelling

• Often makes no sense
• Requires good phonic skills to start
• Requires learning many spelling rules
• And it also requires excellent visual working memory
  – How many of you check spelling by looking at your word written out

Building Listening Skills

• Clear speech that is loud enough to hear without struggling
• Auditory training – listening for words that are different by only one sound
• Environmental modifications – quiet rooms help build listening skills
• Play Attention!

How Teachers Build Brains

• New knowledge builds new connections
• Practice with existing skills builds strength and speed of existing pathways
• Augmenting neurochemistry (neuromodulators) increases attention and enhances retention
Beyond early infancy, plasticity is modulated as a function of:

1. brightness
2. attention
3. judgment of error
4. punishment
5. Reward
6. et alia

See Kilgard & Merzenich, Science (1998)

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)
- et alia

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

Video of Successful English Language Learners