Brain-Based Learning & Literacy

Martha S. Burns, Ph.D.

Disclosure

- I am employed as Director of Neuroscience Education for Scientific Learning Corporation
- I am also an Adjunct Associate Professor at Northwestern University
- I am here at the invitation of Urs Ribary and Marlene Lewis
- I am not being paid for this presentation

Brain-Based Literacy and Learning

- The latest research & developments in how the brain learns and acquires language and literacy
  - Brain Basics & New Discoveries
  - What's Beneficial to Early Brain Development
  - The Teenaged Brain
  - How Teachers and Therapists Change Brains
  - Factors that alter brain maturation
  - Interventions Based in Neuroscience

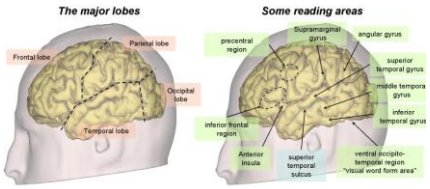
New Research Trends

- Brain Organization & Processing
- Brain Maturation
  - What sets up the brain in the early years for later academic success?
  - Neurodevelopmental factors that affect brain maturation
  - Ways to mitigate interference
  - Even the biggest skeptics are starting to “get it”
- The newest research further supports neuroscience-based interventions

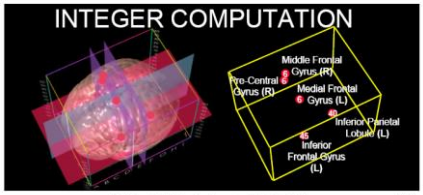
Teachers & Therapists Build & Change Brains

- The human brain is an experience-dependent organ
- Early-childhood experiences prepare the brain to learn
- Teachers build and change brains – that is their main goal
- Research shows that all children can achieve, even those who begin at a disadvantage

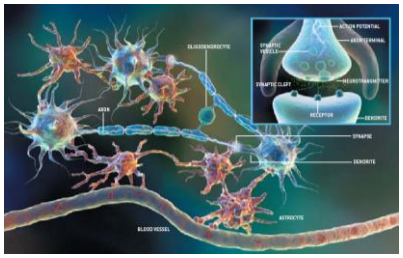
Let’s Review How the Brain Learns



Let's Review How the Brain Learns

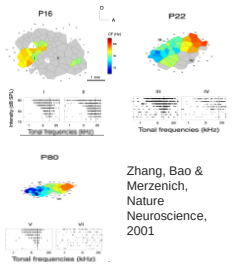


Neuronal Communication System



Brain Building Process

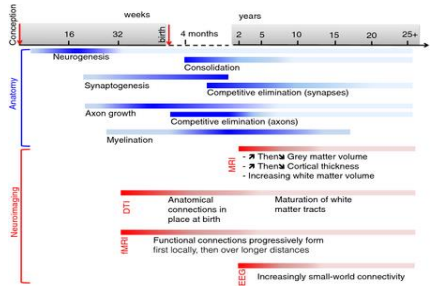
- Proliferation – neighborhood and suburb building
  - Synaptogenesis – neighborhoods connected by yards
  - Axon Development – access roads
- Pruning – clearing out the trees, unpaved roads, old empty houses, and barriers to development
  - Competitive Elimination



Zhang, Bao & Merzenich, Nature Neuroscience, 2001

Brain Regions Build Based on Volume

- Essential for cognition and emotion
  - Language
  - Stress
  - Coordination of the 5 senses into a cohesive experience
- When you work these brain regions you tend to feel
  - Tired
  - Stymied
  - Frustrated
- The building starts just before birth, but is most profound before age 5

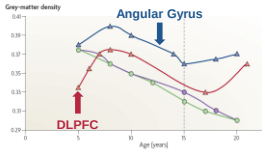


Later Maturation: The Adolescent Brain

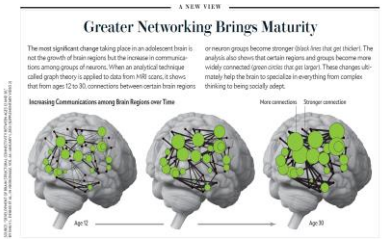
"A mismatch in the maturation of brain networks leaves adolescents open to risky behavior but also allows for leaps in cognition and adaptability" – Dr. Jay Giedd, University of California San Diego

Pruning Refines the Connectomes

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** in purple, and in the **occipital pole** in green.



Greater Networking Brings Maturity


A NEW VIEW

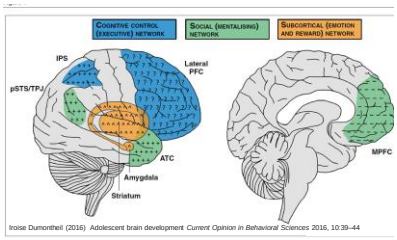
Greater Networking Brings Maturity

The most significant change taking place in an adolescent brain is not the growth of brain regions but the increase in communications among groups of neurons. When an analytical technique called graph theory is applied to data from MRI scans, it shows that from ages 12 to 30, connections between certain brain regions or neuron groups become stronger (black lines that get thicker). The analysis also shows that certain regions and groups become more widely connected (green circles that get larger). These changes ultimately help the brain to specialize in everything from complex thinking to being socially adept.

Increasing Communications among Brain Regions over Time

More connections · Stronger connection

Age 12 · Age 30



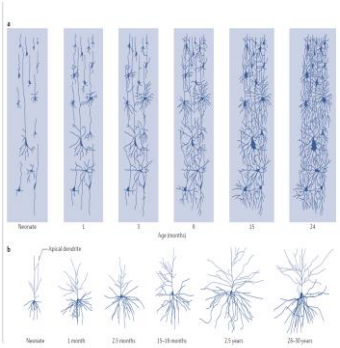
Iroise Dumontheil (2016) Adolescent brain development *Current Opinion in Behavioral Sciences* 2016, 10:39–44

All cortical regions highlighted here show decreased grey matter volume and cortical thickness during adolescence, while amygdala volume increases during adolescence, and striatum volume decreases during adolescence. Age and puberty stage both play a role in structural and functional changes taking place during adolescence. ATC: anterior temporal cortex; IPS: Intraparietal sulcus; MPFC: medial prefrontal cortex; PFC: prefrontal cortex; pSTS: posterior superior temporal sulcus; TPJ: temporo-parietal junction.

How Teachers & Therapists Build Brains

- **Teachers as architects** - New knowledge builds new connections
- **Teachers as regional planners** - Practice with existing skills builds strength and speed of existing pathways
- **Teachers as capacity builders**- Augmenting neurochemistry (neuromodulators) increases attention and enhances retention

Teachers as architects



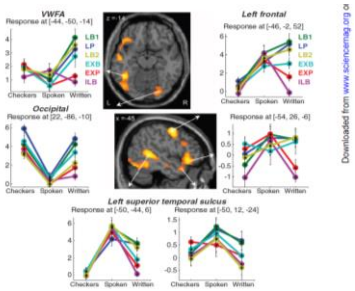
a. The first two years of life
b. Synaptic spine density in the prefrontal cortex – the part of the brain that "does the harder thing" builds through the school-age years until adolescence

Layer III development
Part **b** of the figure.

Gilmore, Knickmayer & Gao, 2018

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

Teachers & Therapists as Regional Planners



Dehaene,

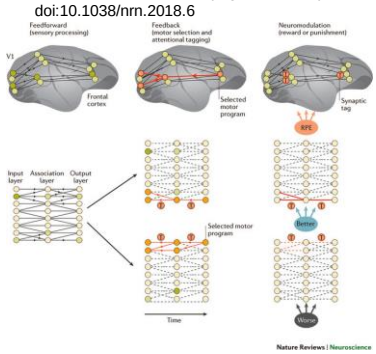
Literacy Enhances Brain Response in Three Ways

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

Roelfsema and Holtmaat, 2018

(*Nature Reviews Neuroscience* **volume 19**, pages 166–180)
doi:10.1038/nrn.2018.6

Effects of network neuroplasticity from Feedforward (bottom up) and Feedback (top down) processing with neuromoduatory control

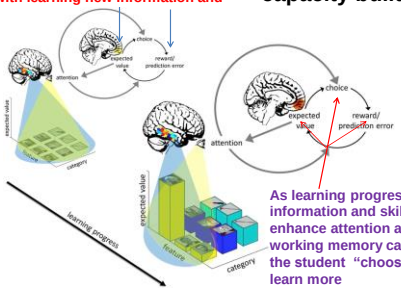


Teachers & Therapists as capacity builders

- Cognitive capacity for learning requires:
  - Attention
  - Working Memory
  - Processing speed and accuracy

Students with strong attention and working memory capacity learn to associate value and reward with learning new information and skills

Teachers as capacity builders



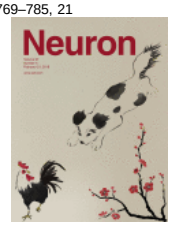
As learning progresses - new information and skills then enhance attention and working memory capacity as the student "chooses" to learn more

A Two-Way Street between Attention and Learning *Tessa Rusch, Christoph W. Korn, Jan Gläscher Neuron* Volume 93, Issue 2, Pages 256-258 (January 2017)

Neuromodulators that enhance attention and memory

- Different dimensions of attention and working memory are modulated by the behaviorally-context-dependent release of:
- acetylcholine (focused attention/reward)
- dopamine (reward, novelty)
- norepinephrine (novelty)
- Serotonin

Thiele and Bellgrove (2018) *Neuron* Volume 97, Issue 4, p769–785, 21



23

Teachers and Therapists Upregulate Neuromodulators During Instruction

- Walking around the classroom maintains alertness (acetylcholine)
- Novel ways of presenting information keeps attention levels high (norepinephrine)
- Timely appropriate reinforcement helps keep students motivated and retain new information (dopamine)

24

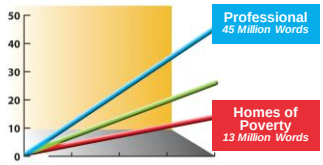
Environmental Influences that Affect Neurodevelopment

- Language exposure in early years
- Nutrition
- Poverty
- Toxic Stress
- Learning English as a Second Language
- Genetic neurodevelopmental differences – Autism Spectrum Disorders and Dyslexia

What Factors Can Affect Brain Maturation?

Any limitation of experience in a given cognitive area will affect maturation

The 32 million word gap



Meaningful Differences in the Everyday Experience of Young American Children by Betty Hart & Todd R. Risley. Paul H. Brookes Publishing Co. (1995).

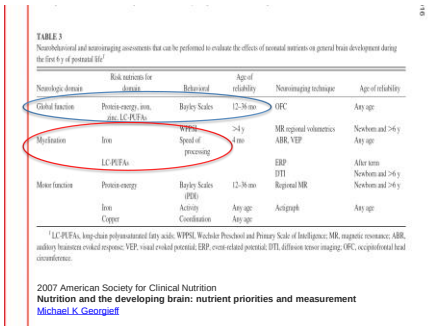


TABLE 3

Neurobehavioral and neuroimaging assessments that can be performed to evaluate the effects of neonatal nutrients on general brain development during the first 6 y of postnatal life[1]

Neurologic domain	Risk nutrients for domain	Behavioral	Age of reliability	Neuroimaging technique	Age of reliability
Global function	Protein-energy, iron, zinc, LC-PUFAs	Bayley Scales	12–36 mo	OFC	Any age
		WPPSI	>4 y	MR regional volumetrics	Newborn and >6 y
Myelination	Iron	Speed of processing	4 mo	ABR, VEP	Any age
	LC-PUFAs			ERP	After term
				DTI	Newborn and >6 y
Motor function	Protein-energy	Bayley Scales (PDI)	12–36 mo	Regional MR	Newborn and >6 y
	Iron	Activity	Any age	Actigraph	Any age
	Copper	Coordination	Any age		

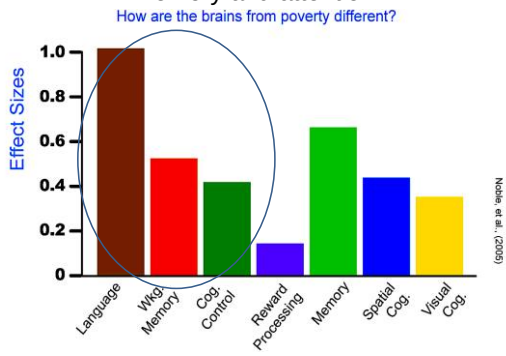
[1] LC-PUFAs, long-chain polyunsaturated fatty acids; WPPSI, Wechsler Preschool and Primary Scale of Intelligence; MR, magnetic resonance; ABR, auditory brainstem evoked response; VEP, visual evoked potential; ERP, event-related potential; DTI, diffusion tensor imaging; OFC, occipitofrontal head circumference.

2007 American Society for Clinical Nutrition
Nutrition and the developing brain: nutrient priorities and measurement
Michael K Georgieff

We have known that income level negatively impacts cognitive functions for over a decade

29

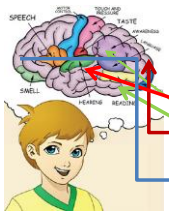
There are links between family income and memory and attention



Family income, parental education and brain structure in children and adolescents Noble, et. al. *Nature Neuroscience* 30 March 2015

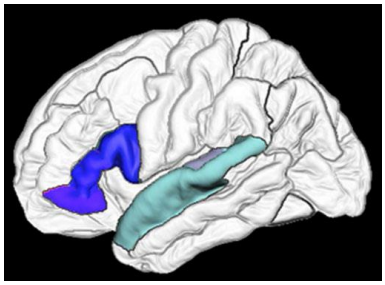
- Among children from lower income families,
  - small differences in income were associated with relatively large differences in surface brain area
- Among children from higher income families, similar income increments were associated with smaller differences in surface area.

Brain structure and poverty
(Noble et al, 2015)

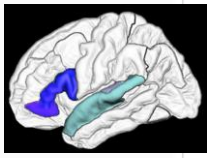


- Brain Structure and income level relationships were most prominent in regions supporting
- ***language***
- ***reading,***
- ***executive functions***
- ***spatial skills***

Studying Individual Differences in Adolescent Brain Development (Foulkes and Blakemore, 2018)



33



(Foulkes and Blakemore, 2018)

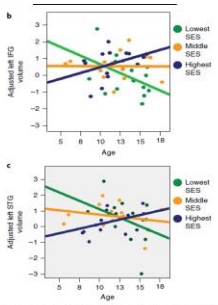


Fig. 4 | SES-by-age interaction in left inferior frontal gyrus (IFG) and left superior temporal gyrus (STG) volume. a, The left IFG (dark blue) and left STG (light blue). **b**,**c**, Plots of the SES × age interaction in (**b**) the left IFG and (**c**) the left STG. Reproduced from ref. [36], Wiley-Blackwell.

Scientific American Mind May 2016

Damage to health and well-being

This wear and tear increases the risk of stress-related physical and mental illness later in life

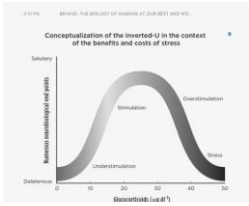
- Extreme exposure to toxic stress changes the stress response system
  - **Responds at lower thresholds** to events that might not be stressful to others,
  - **Activates more frequently and for longer periods** than is necessary, like revving a car engine for hours every day.

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????

There Are Other Effects on Plasticity Like Stress (Sapolsky ***Behave*** 2017)

- Inverted-U effect on change
  - Moderate or transient stress (or exposure to the equivalent glucocorticoid levels) increases spine number in the hippocampus while
  - Sustained stress or glucocorticoid exposure does the opposite
- Depression and anxiety – two disorders associated with elevated glucocorticoid levels – can reduce hippocampal dendrite and spine number- that arises from decreased levels of BDNF



Adverse Childhood Experiences (ACES) (*n* =1007) [Jimenez et al, 2016]

Variable %	(No.)
Child maltreatment	
Psychological	16 (162)
Neglect	13 (132)
Physical	15 (154)
Sexual	0.6 (6)
Household dysfunction	
Maternal depression	12 (121)
Substance use	15 (149)
Incarceration	18 (181)
Violence toward mother	11 (111)

Total ACEs	
0	45 (451)
1	27 (275)
2	16 (158)
3	8 (84)
4	3 (25)
5	1 (11)
6	0.3 (3)

Jimenez et al. Adverse Experiences in Early Childhood (ACES) and Kindergarten Outcomes
PEDIATRICS Volume 137, number 2 , February 2016

Table 3 Teacher Ratings of Below Average Academic Skills – percentages (Jimenez et al, 2016)

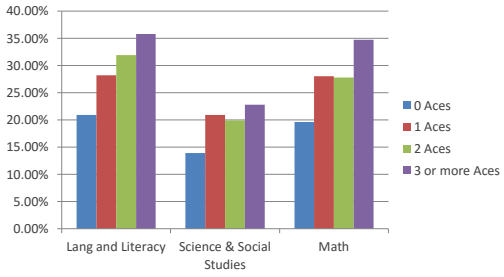
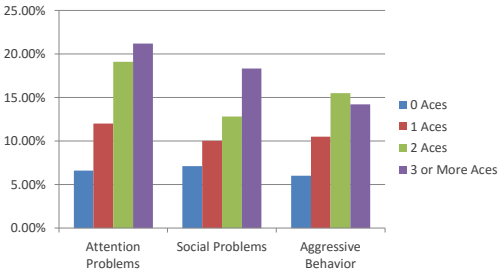


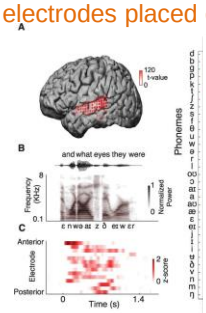
Table 5.Teacher Ratings of Behavior – Percentages
(Jimenez et al, 2016)



The Role of Perception

- Early brain map development of the sound system of our native language is essential for clear perception of speech
  - For learning language
  - For learning phonics
  - For attentional skills
  - For listening skills in school

Researchers can see the actual map using electrodes placed on the temporal lobe



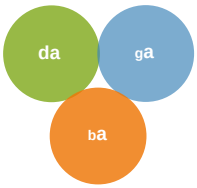
The map continues to refine itself through early childhood based on language experience

Think of these neural clusters as keys on a piano

- Each language has its unique keyboard.
- A child raised with English records a keyboard of the 44 speech sounds or phonemes of English.
- A child raised with Spanish records a keyboard of the 26 phonemes of Spanish.
- Learning a second language requires the brain to build new "keys" – clusters or sets of neurons -- to access the new language accurately and quickly.

The Muddy Perception of a New Language Learner

A) Proficient English

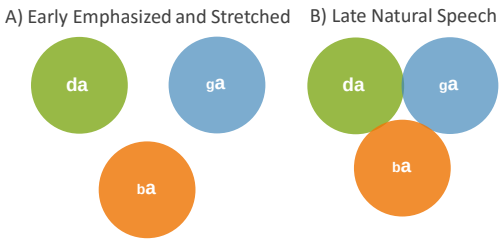


B) Inefficient maps

Re-tuning the Keyboard

- Using the principles of brain plasticity, *Fast ForWord*® exercises build and tune the inner keyboard for English.
- Perceiving and sounding out English words becomes easy and automatic.
- The exercises that build the English keyboards for ELL students also correct mushy keyboards in the brains of struggling readers.

Training Phoneme Examples



Why Students Forget—and What You Can Do About It

- Our brains are wired to forget, but there are research-backed strategies you can use to make your teaching stick.

48

Interventions that Provide Support

- Encourage and check organizational tools
  - Resources such as backpacks, folders, notebooks, spirals, planners (digital or physical), binders (digital or physical, such as eBinders) that are utilized to organize materials and/or time
- Explicitly teach organizational skills
  - Specific expertise that students need in order to utilize organizational tools
- Help students establish organizational routines
  - The habitual use of organizational skills and systems, integrated into normal practices and procedures

Interventions that Provide Support

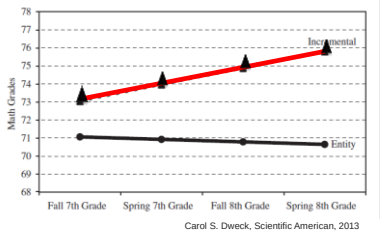
To accomplish this, educators are encouraged to:

- Establish systems for providing regular feedback to guide refinement
- Scaffold from teacher-directed towards student ownership
- Recognize and provide space for student individuality

Growth Mindset

- When teachers believe all students can learn, they do!
- "Students who believe intelligence is malleable (growth mindset) earned higher math grades in the fall of 7th grade than those who believe in static intelligence (fixed mindset) even though the groups had equivalent math achievement test scores in the 6th grade" – from *Implicit Theories of Intelligence Predict Achievement*. LS Blackwell et al., Child Devel., Vol. 78. No 1.

Growth Mindset – When Teachers Believe All Students Can Learn They Do!



Carol S. Dweck, Scientific American, 2013

Students who believe intelligence is malleable (growth mind-set) earned higher math grades in the fall of 7th grade than those who believe in static intelligence (fixed mind-set) even though the groups had equivalent math achievement test scores in the sixth grade. *From Implicit Theories of Intelligence Predict Achievement. LS Blackwell et al.,* CHILD Devel., Vol. 78, No. 1

GEORGE LUCAS EDUCATIONAL FOUNDATION
edutopia

- Building a Metacognitive Classroom
- Teaching students about neuroplasticity and the brain's potential can have a positive effect on their self-perceptions and expectations for success in school.
- By Donna Wilson and Marcus Conyers
- February 21, 2018

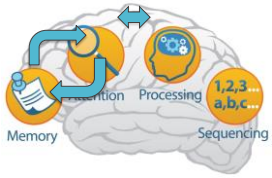
Technology & Teachers Can Revamp Schools –Teaching **Smarter** not ***Harder***

- The science of learning and EdTech
- New software to personalize learning
- EdTech must be at the service of teaching, not the other way around

The Role of Neuroscience Technology- Build Perceptual, Language and Cognitive Skills

- Carefully designed neuroscience-based technology
- **Builds the underlying capacities that are impacted in children of poverty and children with learning disabilities**

Executive Function + Cognitive Skills



56

Why Enhance Cognition?

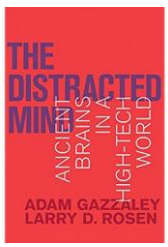
- *KQED 4/11/18: BIG IDEAS: A Futuristic Look at Assessing Learning*
- Adam Gazzaley – a neurology professor and co-author of *The Distracted Mind: Ancient Brains in a High-Tech World* argues that we are experiencing a "global cognition crisis."

Adam Gazzaley, KQED 4/11/18

- Enhancing human cognition is not about increasing the amount of information we teach students.
- Education has been built on "**transferring information content, but not really building the underlying information processing systems that this depends upon**."
- In contrast, some fields "have focused in an almost frenetic way on optimizing abilities,".
- Take physical fitness, where humans have developed specialized equipment and methods for improving balance, coordination, flexibility, strength, endurance and speed.

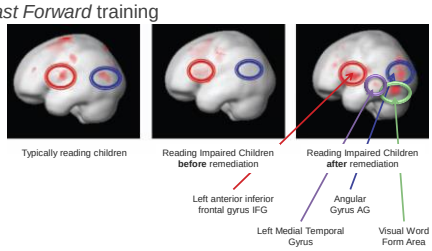
Adam Gazzaley, KQED 4/11/18

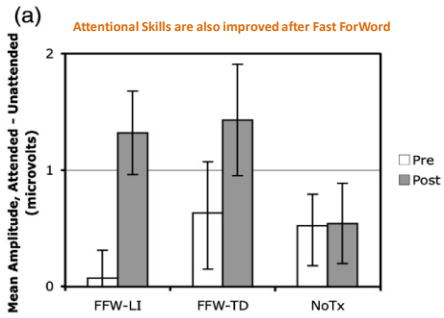
- Cognitive control, or "the mental abilities that enable us to enact our goals" include:
- **Attention**: the ability to direct limited mental resources when and where we need them
- **Working memory:** the slots available in our short-term memory to problem-solve the task at hand
- **Goal management:** how and when should we multitask -- or more precisely "task switch" -- knowing that every time our brain has to switch, it taxes our mental resources



When you address cognitive skills

Language and reading areas are activated after a short period (six weeks) of neuroscience-based intervention *Fast Forward* training





Courtney Stevens, et al. *B R A I N R E S E A R C H* 1 2 0 5 (2 0 0 8) 5 5 – 6 9

When Brain Training Works – Some conditions

Posted on August 23, 2016

Condition 1: Training must adapt to performance, require effortful attention, and increase in difficulty

- **The design of the training program needs to be motivational, engaging and reward, not just demand, persistence.**

Send

On April 3, 2018 The Council of Administrators of Special Education Extended Endorsement of Fast ForWord Program from Scientific Learning Corp.

The CASE review committee commended the research-based Fast ForWord Program for:

1. ***continuing improvements***
2. ***updates and enhancements***
3. ***which enables students with learning disabilities to achieve quick and lasting learning gains***

64

Literacy Worldwide Endorsement

Five Ways to Help Struggling Readers Build Reading Fluency
BY SHANNON GILFEATHER
Apr 18, 2018

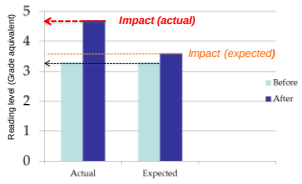
"Digital guided reading tools can help. One example is the Fast ForWord program, which provides a guided reading tool that uses speech verification technology to give real-time corrective feedback to students as they read aloud, like a guided reading coach. This type of technology can be particularly helpful with hard-to-engage students who may be more willing to practice reading aloud with a digital tool that listens without bias or judgment."

FFW Training Programs in BC Schools

	Number of Students	Average Attendance	Average Participation	Average of Total Days Trained	Average # Of Products Completed	Average Percent Complete Across Products
2008-2012	**3,140**	71.5%	91.5%	42.7	0.74	72.2%
2012-2014	**2,928**	69%	90%	75	0.8	70%
2014-2016	**2,750**	61%	87%	70	0.6	70%

Overall Impact (gain):

Children at Grade 5.3, but reading at average level Grade 3.3 gained ***0.7 - 2.0 years in reading level*** *over 5 months*



- *In 8 years, Interventional* ***FFW Training Platform has grown to more than 130 schools*** *across* ***22 school districts*** *in BC, and* ***more than 8,818 students*** *have been trained.*

BC FFW Consortium

Fast ForWord Programs were Finalists for Language Learning and Programs for Children with Special Needs

THE EDTECH AWARDS
BROUGHT TO YOU BY EDTECH DIGEST

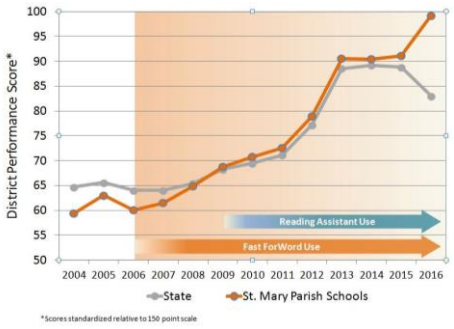
2018 – Finalists & Winners

THE EDTECH AWARDS
2018 | **Moving Forward**

Condition 2: Protocol

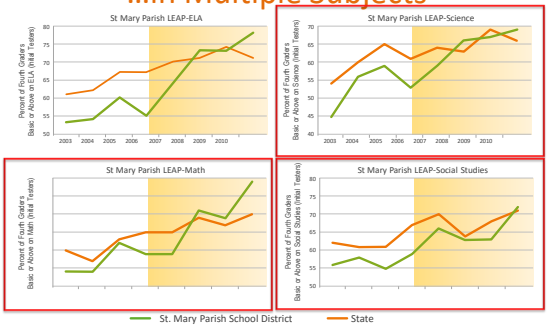
- It requires a minimum “dose” of 15 hours total per targeted brain function performed over 8 weeks or less.
- It’s refreshing, actually, to see a consensus emerging that a few minutes or hours of training here and there won’t do much for cognitive fitness.
- **a dramatic impact on multiple brain functions is achieved in 35 to 50 hours of training in an integrated fashion**

Accelerating Growth – District Wide



70

…in Multiple Subjects



The Fast ForWord K-12

Fast ForWord + Reading Assistant

Provides a complete intervention solution for struggling learners:

1. tools for building the foundational cognitive capacity so often under-developed in students of poverty and other subgroups;
2. tools for building strong language skills in struggling learners; and
3. the tools for practicing key literacy skills to build fluency, comprehension, and vocabulary

What Works Clearinghouse

#1 Rated Intervention for improvement in English Language

Intervention	Improvement Index	Effectiveness Rating
Fast ForWord® Language	31	+
Instructional Conversations and Literature Logs	23	+
Read Well®	21	+
Peer Tutoring and Response Groups	17	++
Vocabulary Improvement Program for English Language Learners and Their Classmates (VIP)	17	+
Bilingual Cooperative Integrated Reading and Composition (BCIRC)	11	+
Arthur	11	+
Read Naturally®	9	0
Enhanced Proactive Reading	-1	0

Source: http://ies.ed.gov/ncee/wwc/findwhatworks.asp The table has been reformatted to fit this slide.

Summary & Conclusions

- The human brain is an experience-dependent organism
- Education provides a 30 hour per week set of essential experiences that build important brain skills
- Students with learning disabilities or restrictive life experiences have neurodevelopmental differences, but well-designed neuroscience interventions are effective at building underlying capacities that enable effective learning