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PUSHING THE BOUNDARIES OF ACHIEVEMENT
A SERIES ON THE LATEST EVOLUTION OF APPLIED NEUROSCIENCE

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ur Panelists

Alex Kitzes Ph.D.
Clinical Psychologist & Co-Founder of Stronger Brains Inc, USA

Cheryl Chia
Physiotherapist & Founder of Singapore-based BrainFit

Dave Stanley
Director of Learning Ecosystems at LearnFast Australia

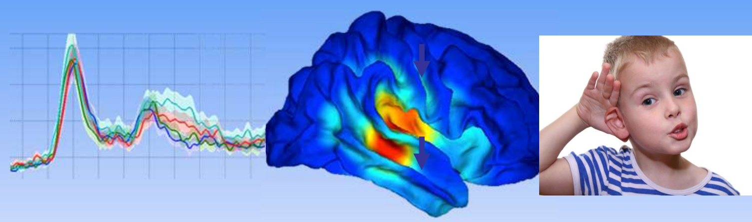
Your Presenter – Paula Tallal, Ph.D.

Paula is a research scientist, professor, board certified clinical psychologist and entrepreneur. She received her B.A from New York University and Ph.D from Cambridge University. Over the past 40 years she has held academic positions at Johns Hopkins School of Medicine, University of California San Diego School of Medicine, Rutgers The State University of New Jersey and The Salk Institute for Biological Sciences and received continuous funding from NIH and NSF for her scientific research.

She is a Board of Governor's Professor of Neuroscience Emeritus at Rutgers, where she Co-Founded the Center for Molecular and Behavioral Neuroscience. She is currently an Adjunct Professor of Neuroscience at The Salk Institute for Biological Studies in San Diego.

In 1996 Tallal Co-Founded Scientific Learning Corporation, the company that has brought Fast ForWord® to over 3 million struggling learners around the world. She is a sought -after international authority and keynote speaker on language and literacy development and disorders with over 200 academic publications. She was honored to be invited to present testimony to the U.S. Congress on Dyslexia.

Improving Educational Outcomes by Enhancing the Perceptual, Cognitive & Language Skills of Students



Paula Tallal, Ph.D.

Salk Institute For Biological Studies

Research funded by NIH and NSF

Disclosure: Co-Founder, Scientific Learning Corporation, the developer of Fast ForWord® Training Programs

I would like to thank Elite Performance Solutions for inviting me to present our work here today.

News Flash !

Spoken language communication is the foundation upon which social/emotional, behavioral, academic and occupational outcomes depend.

For a variety of biological, social and cultural reasons, increasing numbers of children are entering school without sufficiently strong spoken language skills on which to build adequate literacy and other academic skills.

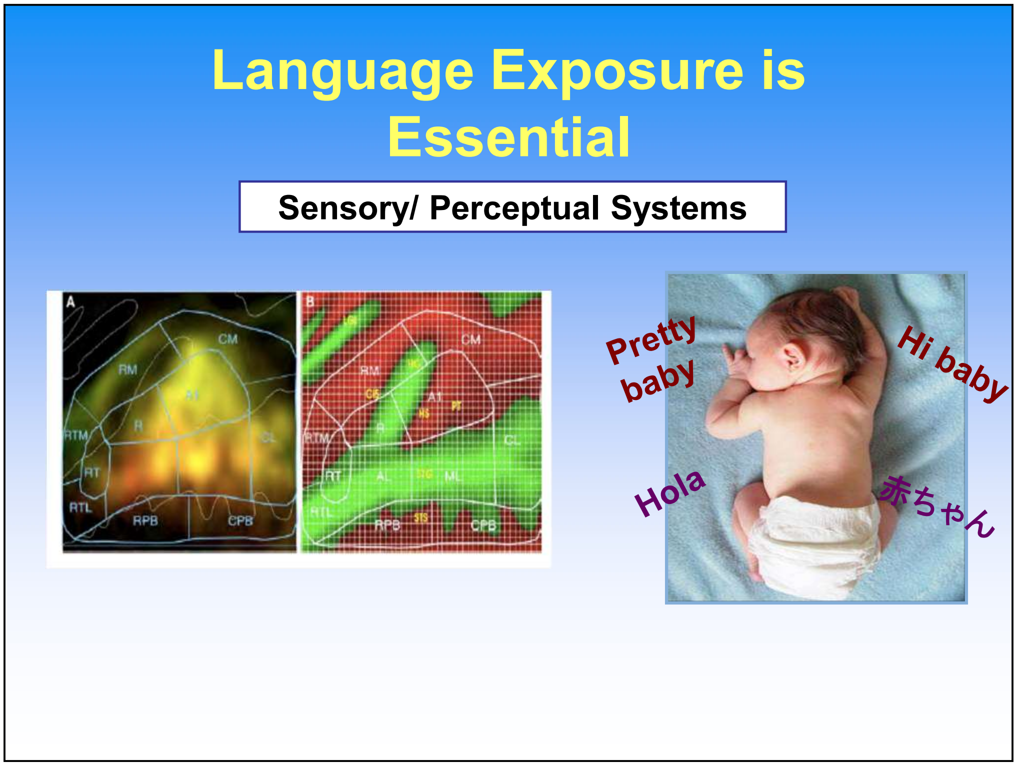
The most effective route to improving reading, academic and social competency is to strengthen the basic perceptual, cognitive and linguistic skills that build language communication proficiency.

Neurobiology of Language

- Our research has focused on understanding the neurobiological and environmental basis of individual differences in language development and disorders.

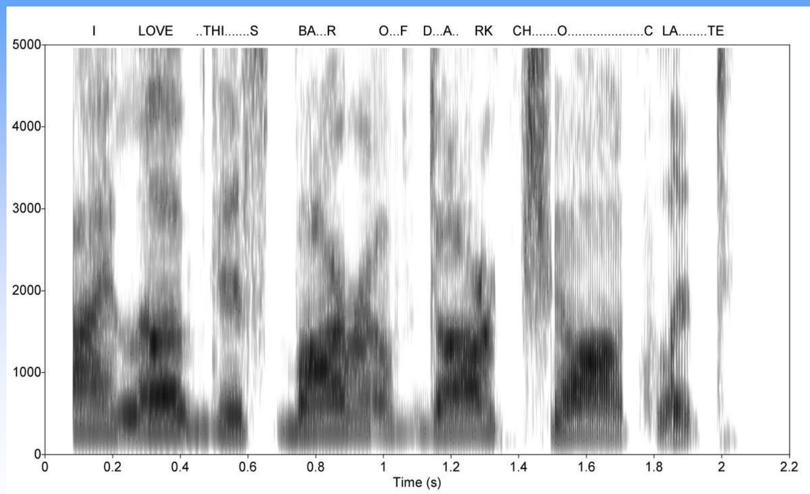
- We began our research program with the observation that many children, who are not deaf or intellectually impaired, but nonetheless have developmental language impairments and reading deficits (dyslexia), have particular difficulty at the phonological (speech sound) level of language.

Read slide first. But, why are they having these problems? To understand deficient language development we need to understand how the brain normally learns language .



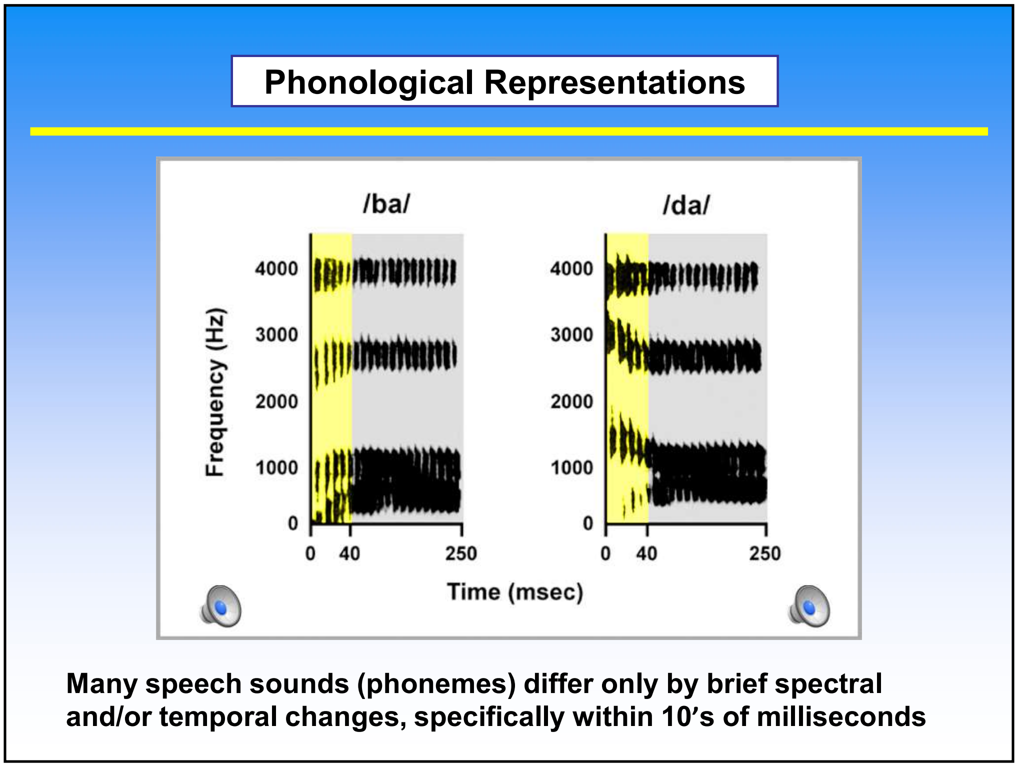
So, let’s start at the beginning. While it is true that language is innate, and does not need to be explicitly taught, **quality** language **exposure** IS critical for language development. Well before the child begins to talk, aural (spoken) language development begins with an infant being **exposed** to the **sensory and perceptual features** of the complex acoustic waveform of the speech they hear all around them.   “Hola nina”,. What a pretty baby you are”. But, of course, the infant doesn’t know any words much less what language they will be learning. So, **what** is their brain actually receiving?

Ongoing acoustic waveform of a spoken sentence –shown as frequency and amplitude across time



As we speak, we move our speech articulators from one position to another very rapidly in sequence to form speech sounds (called phonemes), words and sentences. The complex acoustic signal that is produced as we speak (as seen here) is comprised of a combination of acoustic features, including frequency (pitch) and amplitude (loudness), that change very rapidly in succession, across time as we speak.

Infants who hear normally, and have **sufficient exposure to speech**, begin to detect **frequently repeating acoustic patterns** within speech and learn the **statistical probability** of **which** acoustic patterns are likely to occur **together** or **sequentially in their language**. Their brain begin to **chunk** the ongoing speech waveform into **smaller**, **repeating** segments that acoustically represent **phonemes and** syllables in their language, such as /ba/ and /da/.



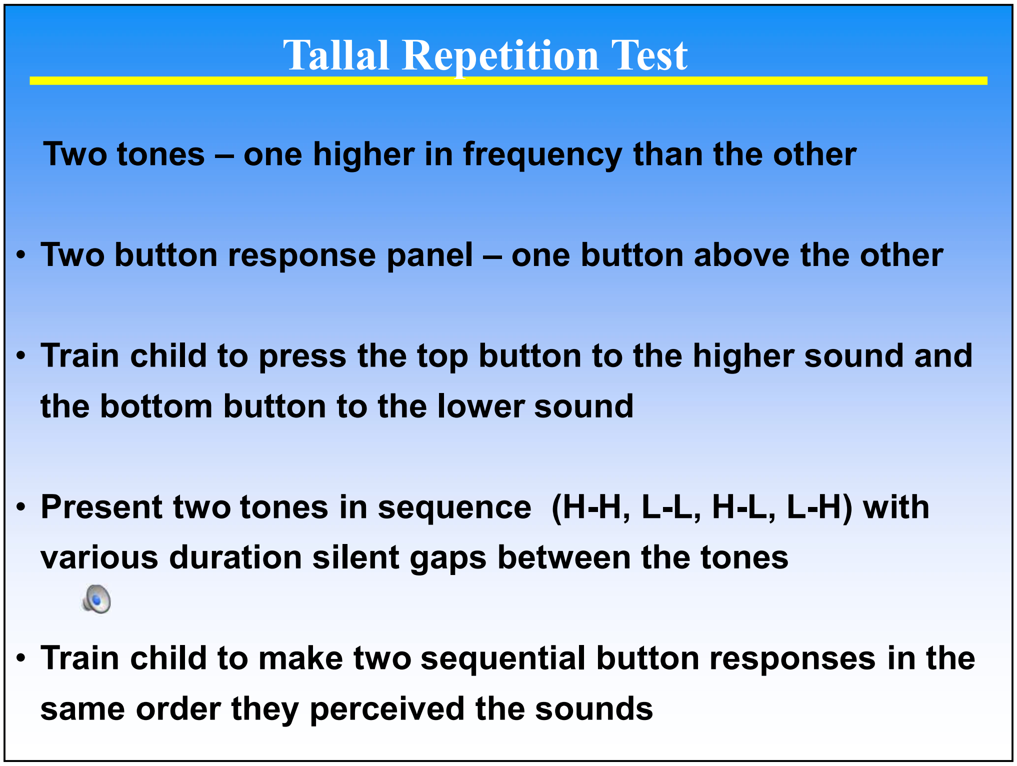
Phonemes, such as /ba/ and /da/, shown here as frequency change over time, are the **smallest acoustic segment of sound** that can change the **meaning** of a word in a language – for example, when the phoneme /b/ is replaced by /d/ the word changes from "bad" to "dad".

Phonemes are the **building blocks** for syllables and words. So clearly and accurately detecting, segmenting, discriminating and neurally representing the phonemes of our native language is an **essential prerequisite** for **all** higher aspects of language development. It is important to note that phonemes are also the sounds within words that written letters represent.

Developmental Language Impairment (LI)

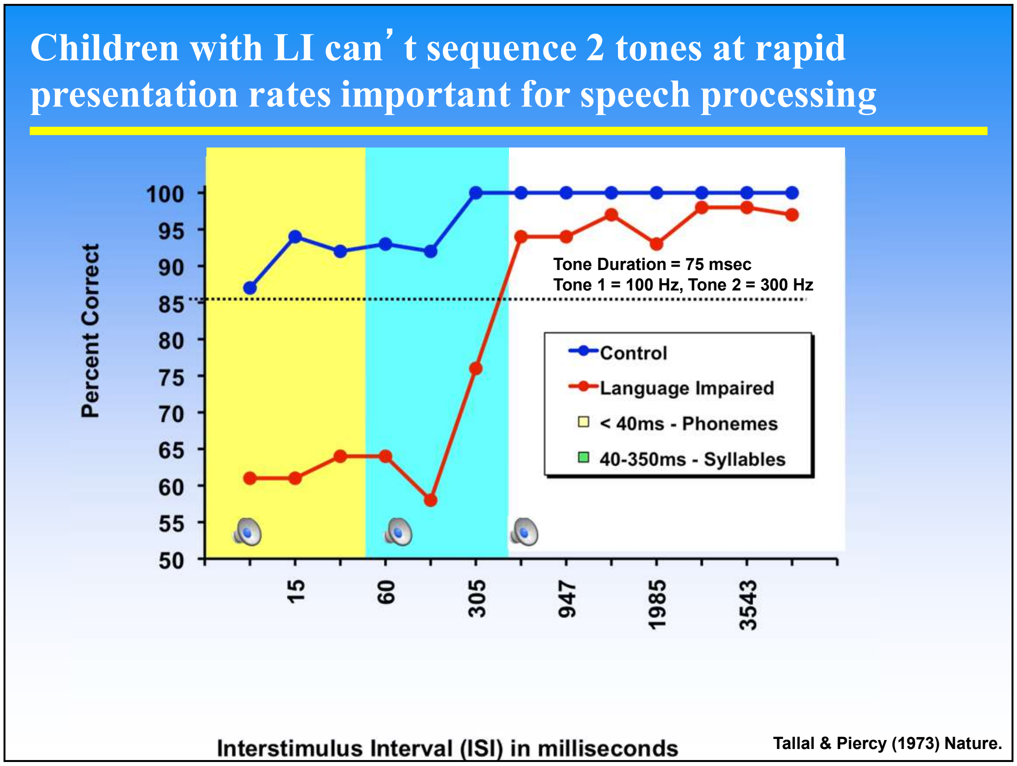
- **These children have normal hearing, but impaired speech processing.**
- **Are they impaired on any aspects of non-verbal central auditory processing?**

Now, let's return to the **mystery of developmental language impairments**. We know these children have **normal hearing**. Yet, they are **impaired** in speech processing and language development. Beyond hearing at the level of the ear, sound must travel through the brainstem to the cortex to be processed as speech. What was **not** known when I started my research was whether these children might be impaired on any higher levels of auditory processing that are critical for speech perception. To investigate this question I developed a hierarchical series of simple **non verba**l auditory processing tasks to systematically test each level of sound processing along the auditory pathway, from the ear to the brain.



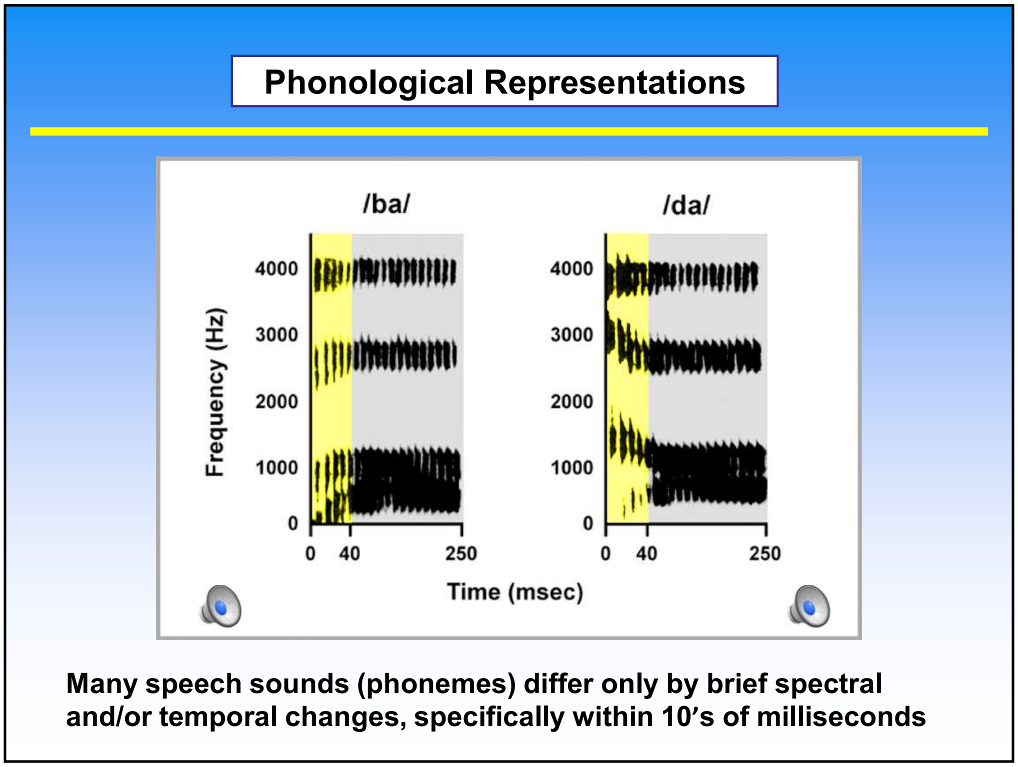
The auditory processing tasks I developed, now know as the Tallal Repetition Test, used only two complex tones, one higher in frequency than the other, and a two button response panel. First, only one tone is presented at a time and children are trained to press the top button for the high tone and the bottom button for the lower tone.

Once this association is learned, **two tones** are presented **in sequence**. The two tones are separated by a gap of silence **of various durations**, known as an Inter-stimulus-interval,**.** Children are trained to make **two sequential** button responses, in the **same order** they perceived the sounds. (sing tones H-L, H-H)



Results showed that there was no difference between children with delayed language development and typical language development in ability to learn this task when single tones were presented. This slide shows the percent correct performance when **two tones are presented sequentially**, separated by various duration gaps of silence (Inter-stimulus-intervals), Results show that there is NO difference between children with impaired vs typical language development in their ability to discriminate, sequence or retain two tone sequences presented with longer gaps of silence (PLAY longest one) .

However, when the same 2-tone sequences are presented more quickly, with shorter silent gaps, (PLAY 60 msec), or even faster at 8ms (PLAY) the language impaired children are virtually at chance.. These results show that children with LI are impaired in processing **non-linguistic** tone sequences, when they are presented within a **10s of ms time range. Importantly, this is the time range** that is essential for processing phonemes(highlighted in yellow) and syllables (highlighted in teal) when spoken within words and sentences in real time.



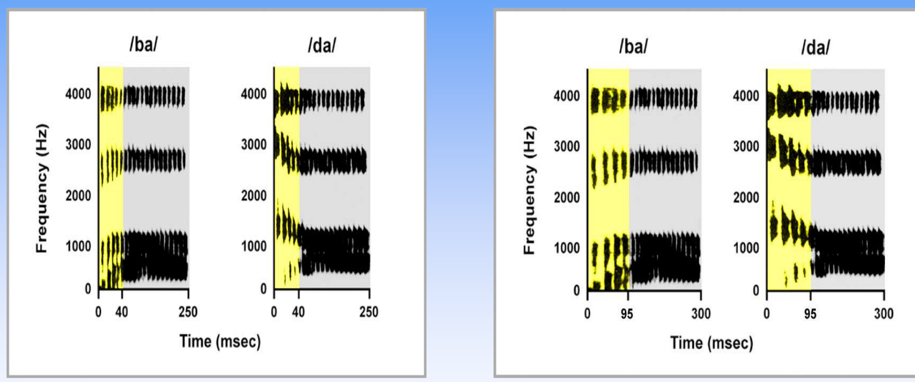
Let's look again at the acoustic waveforms for the syllables /ba/ and /da/. Note that these syllables can **only** be differentiated based on the critical first 40 msec (highlighted in yellow) where there is a very rapid **frequency sweep** (known as **a formant transition**) from lower frequencies to higher in the case of /ba) vs from higher to lower for /da/.

Because of how quickly these formant transitions occur in speech, and the critical role they play in ongoing speech perception, processing the ongoing speech waveform **in real time** is one of the fastest thing the human brain has to do.

My studies done using rapidly presented **non-verbal tone sequences** led me to hypothesize that children with LI would have great difficulty discriminating between speech sounds, such as /ba/ and /da/ that have formant transitions that require processing in the 10's of ms time range.

When tested, the majority of children with LI were found to be **selectively impaired** in their ability to discriminate between these and many other syllable contrasts that require rapid auditory processing, but NOT those that did not. This result suggested that rather than having a **linguistic deficit per se**, LI children's language deficits may stem from a more primary, **non-linguistic rapid auditory processing problem.**

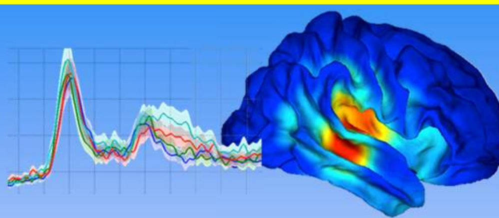
Speech can be computer modified to extend in time the duration of formant transitions



To further demonstrate that this speech processing deficit was **specifically** related to the **rate of change** of the acoustic waveform within speech, rather than phonemic per se, I use computer synthesis to **extend in time the duration** of the formant transitions within the syllables /ba and da/, from 40ms to 80 ms, while maintaining their phonemic identity.

Remarkably, while less than 20 % of children with LI were able to discriminate between these syllables with typical duration (40 msec) formant transition, 100 % were able to discriminate between these same syllables when the duration of the formant transitions was extended to 80 ms. .

Summary

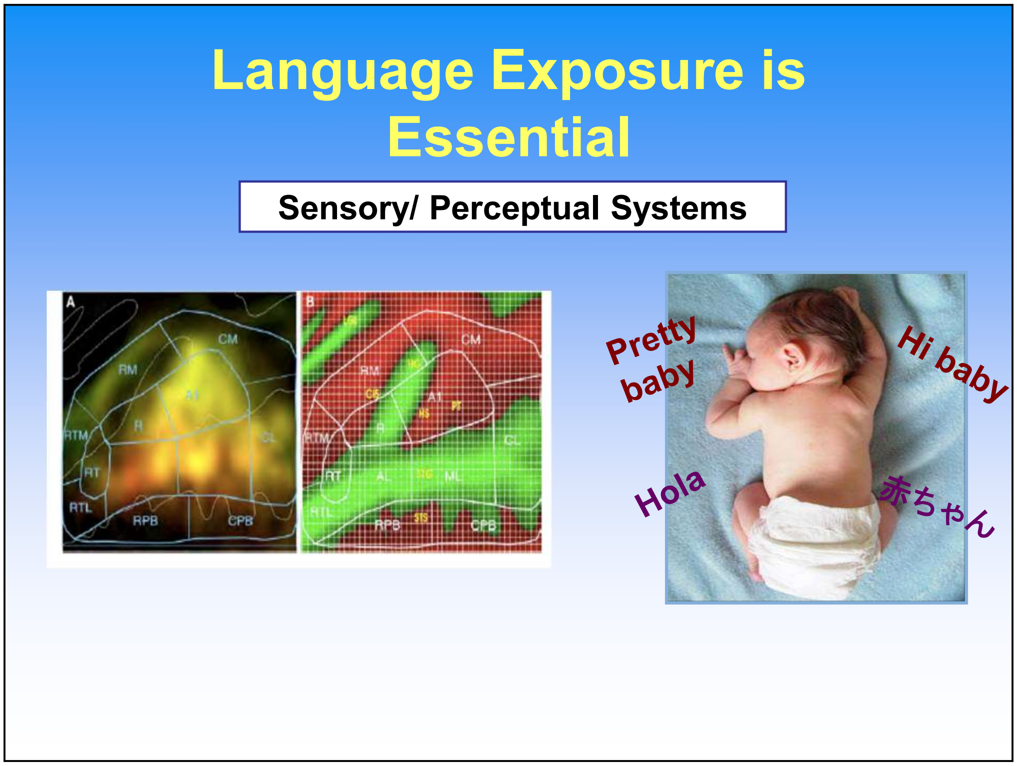


Our studies led to the discovery that language impaired children have particular difficulty in both perceiving and producing brief, rapidly successive signals, **specifically in the tens of millisecond time range**. This is the time range essential for processing phonemes, the basic building blocks for words, in both spoken and written language

Neurobiology of Language

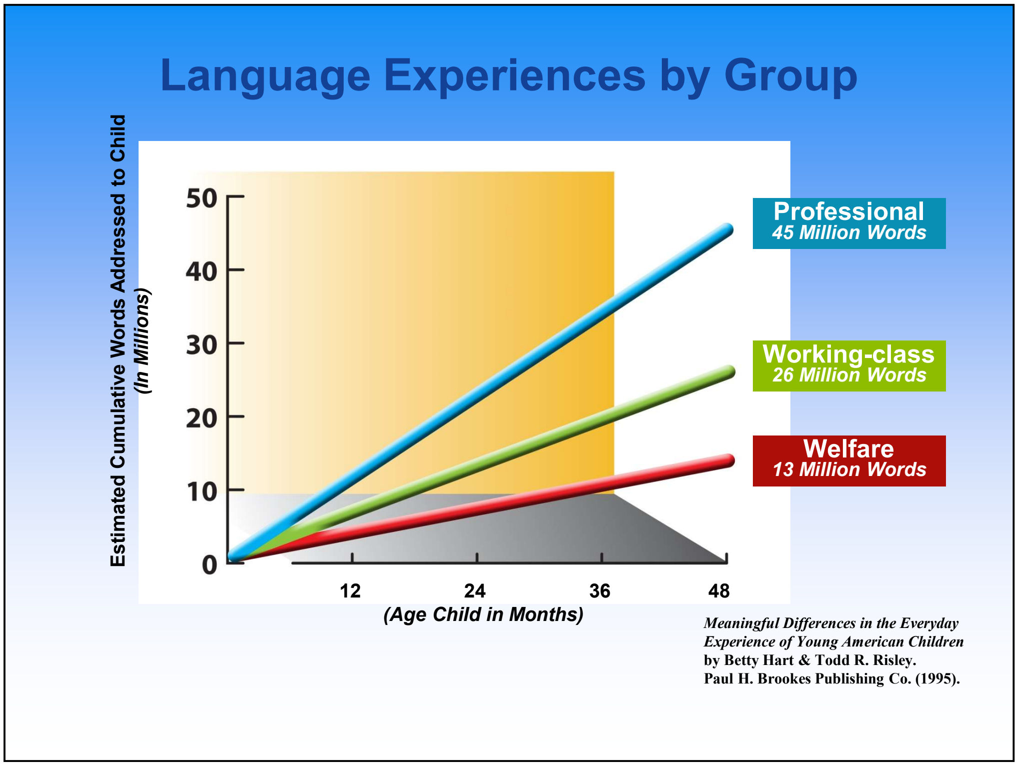
Subsequent studies discovered that difficulty in both perceiving and producing brief, rapidly successive signals:

1) **extended to attention, sequencing and memory problems**
2) **extended to other populations of struggling learners (ADHD, Autism, Dyslexia)**
3) **extended to English Language Learners (ELL)**



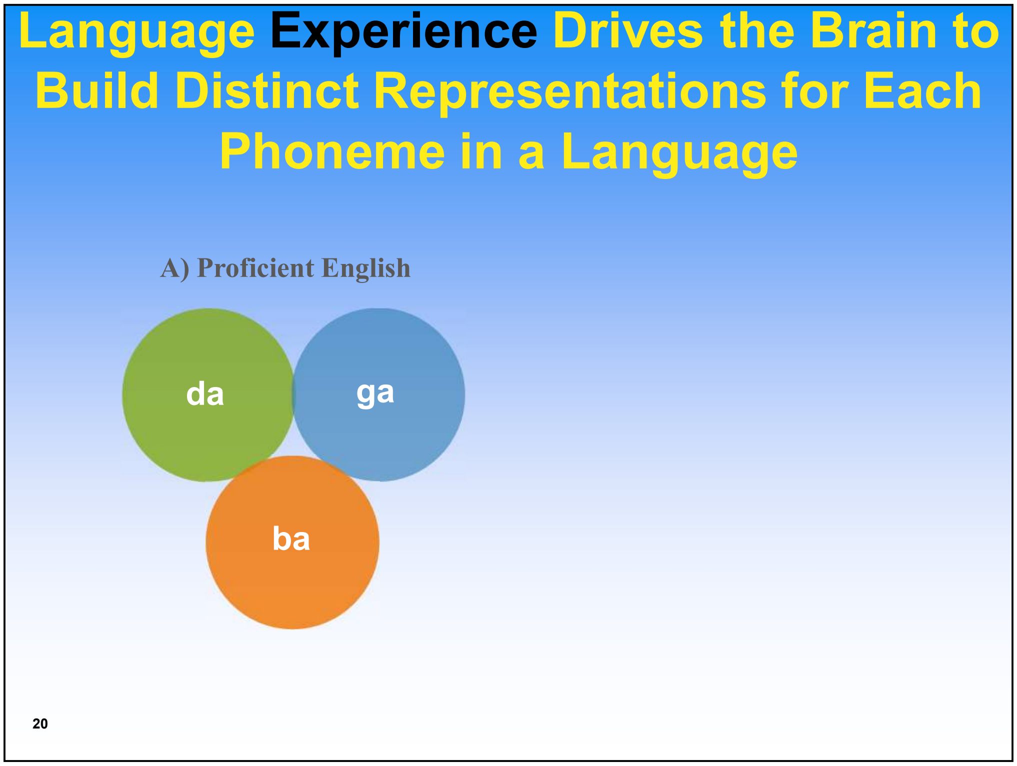
While it is true that there can be a genetic component to language disorders resulting in language problems aggregating in some families, it is also the case that many children with deficient language development have no family history of language disorders. Recall that while is true that language is innate, and does not need to be explicitly taught, **quality** language **exposure** IS critical for language development. Well before the child begins to talk, aural (spoken) language development begins with an infant being **exposed** to the **sensory and perceptual features** of the complex acoustic waveform of the speech they hear all around them.

Unfortunately, not all infants receive the extent and quality of language exposure they need for this process to unfold optimally.

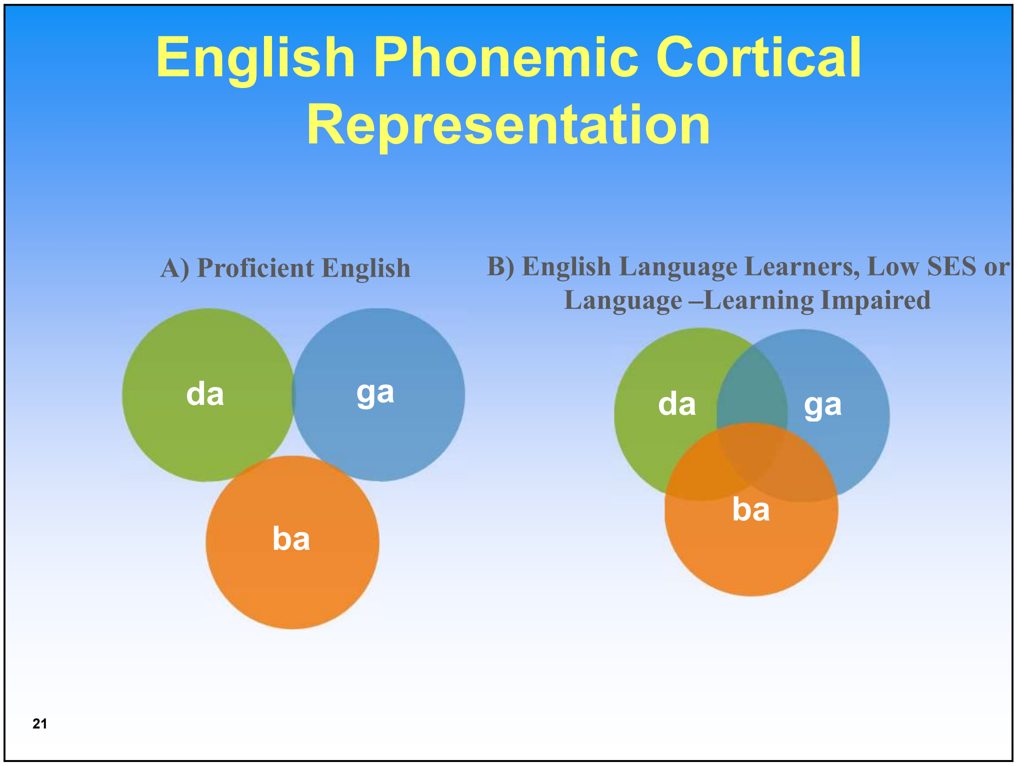


We see here that socio-economic-status has a major effect on the sheer number of words spoken to a child from infancy through age 4 years. Children from low socio-economic families have a 30 million word deficit by the time they enter kindergarten compared to those from high socio-economic families in the US. Further follow up studies have shown that a child's vocabulary at age 4 is one of the best predictors of a child's reading development by the third grade.

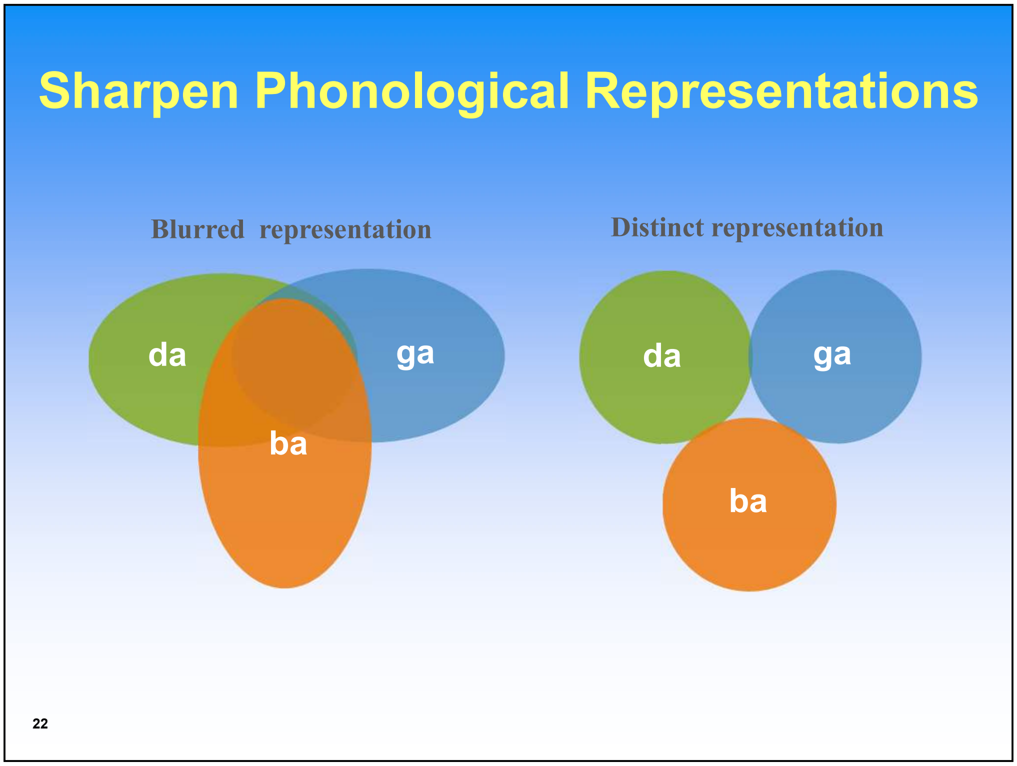
Lack of sufficient exposure to sounds and words in infancy and early childhood, due to poverty and low socio-economic- status, will result in a lack of sufficient opportunity for a child's brain to experience rapidly successive acoustic processing and hence to learn the statistical probabilities of which acoustic patterns are likely to occur together or sequentially, which is essential to build distinct neural representations of phonemes that are so essential for both spoken and written language.



Simple cortical model showing the largely separate cortical representations of example phonemes for individuals proficient in English

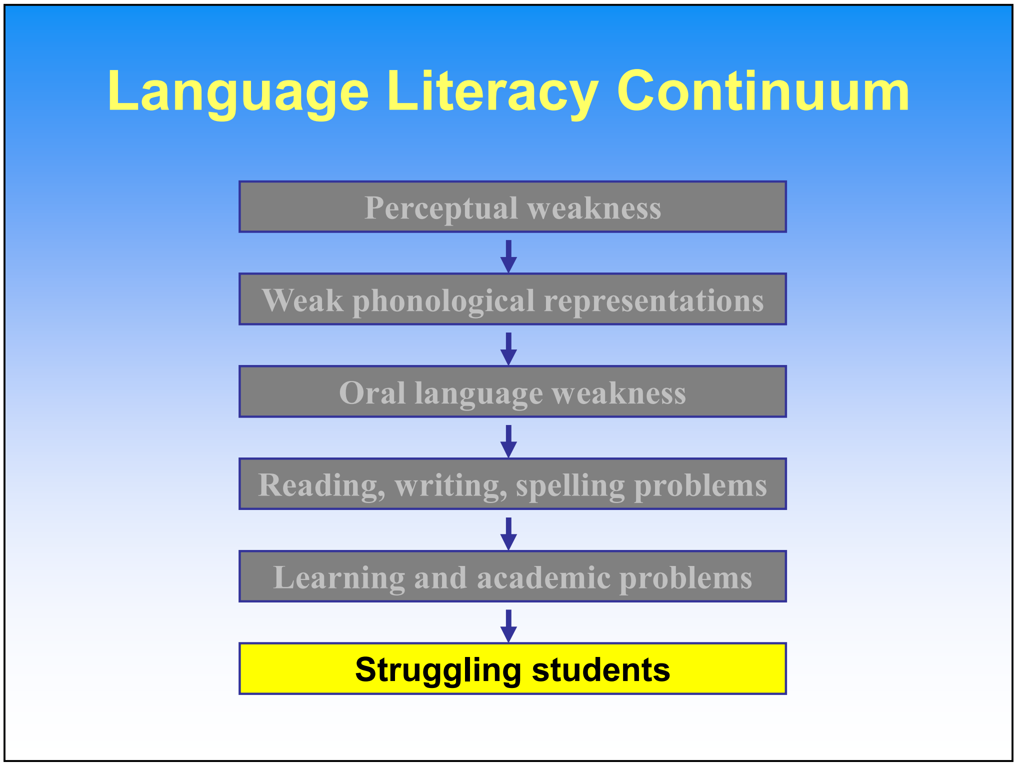


Simple cortical model showing the largely separate cortical representations of example phonemes for individuals proficient in English (A) versus overlapping (blurry) cortical representations for children struggling with English language learning for a variety of reasons.



Establishing distinct neural representations for the individual phonemes in a language forms the foundation for all subsequent language and literacy skills. For reading, distinct representations are essential as students must become aware that it is the small sounds in words that the letters represent. When phonological representations in the brain are blurry or muffled, the brain must use precious processing resources at the phonological level that should have been automatized very early in life. This reduces the neural processing resources available for processing the higher level aspects of language as well as for learning letter sound correspondences for reading and spelling.

There are many reasons why students may have failed to develop distinct phonological representations early in life. These can include early ear infections, genetic predisposition to language-based learning disabilities such as dyslexia, living in a noisy environment or lack of sufficient exposure to clear speech (which have been shown to be prevalent for children living in poverty). Individuals learning a second language beyond the critical early language learning years will also have blurred representations for phonemes in their second language.



Our research has led us to develop what we refer to as the Language to Literacy Continuum.

Virtually all interventions aimed at addressing struggling readers focus on strengthening reading skills. However, the language to literacy continuum shows that to be most effective, goals for intervention must begin with (read slide)…

This intervention continuum was applied to the development of a novel family of training programs known as Fast ForWord.

Why have schools failed to focus on improving fundamental perceptual, cognitive and linguistic capacities ?

It is commonly believed that children enter school with differing genetically and/or environmentally endowed brain capacities and that teachers must just make-do with these individual differences in neural capacity. Recent breakthroughs in the neuroscience of learning, specifically neuroplasticity, have demonstrated that this view is fundamentally wrong.
(Merzenich and Jenkins, 1993).

We know from decades of research with human as well as non-human subjects that highly repetitive experience is required to set up an organization in sensory and motor systems of the brain at the cellular level. This experience dependent learning is known as neuroplasticity, where the brain is molded by repetitive practice. Just think about becoming proficient at your golf or tennis stroke or playing a musical instrument – it requires repetition, repetition, repetition. Even the most proficient pianist still practices the scales, repetitively exercising the fluidity of their motor sequencing skills daily before delving into practicing their piece of music.

Variables Driving Neuroplasticity

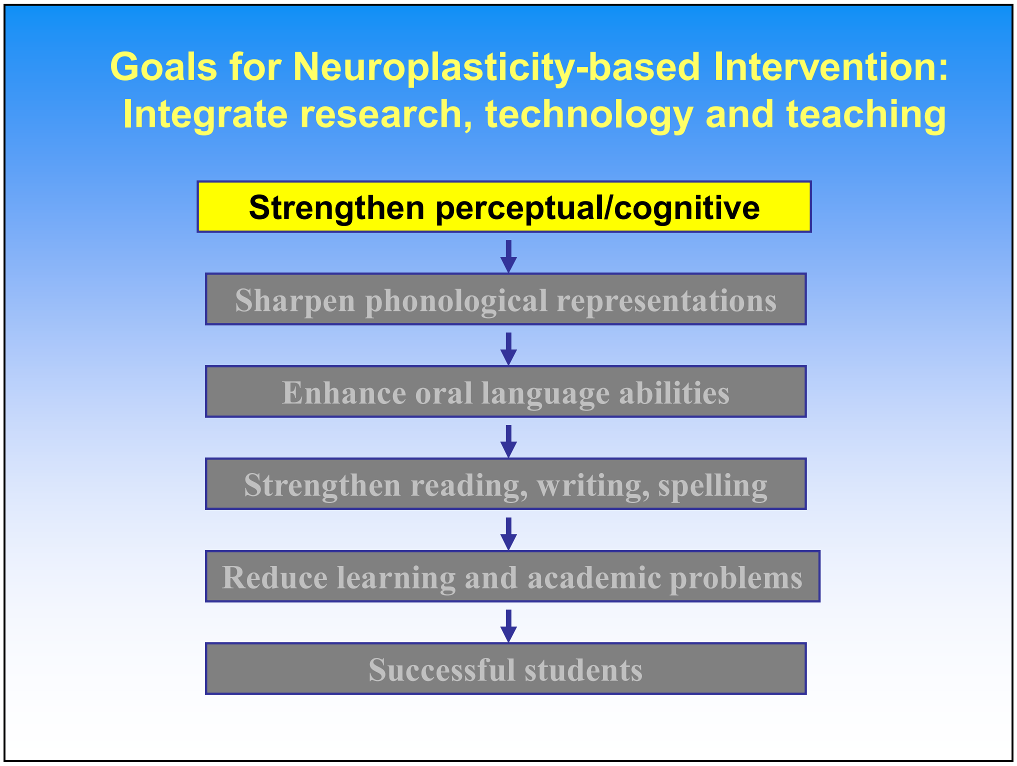
Frequent / intense input

Adaptive trials

Sustained attention

Timely rewards

Many detailed studies have been done over several decades to determine what variable are necessary to drive neuroplasticity most efficiently.. These include :

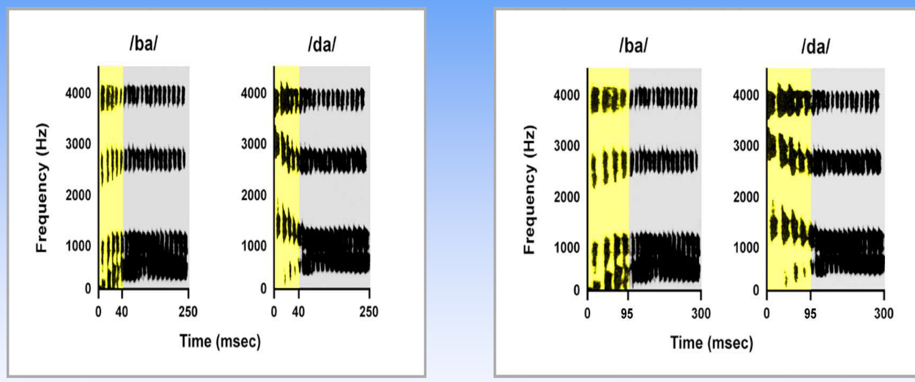


So it is with our Fast ForWord intervention for language and literacy problems. We begin with strengthening perceptual fluidity utilizing a neuroplasticity based method before proceeding to strengthening higher level skills. We incorporated two approaches based on our basic research.

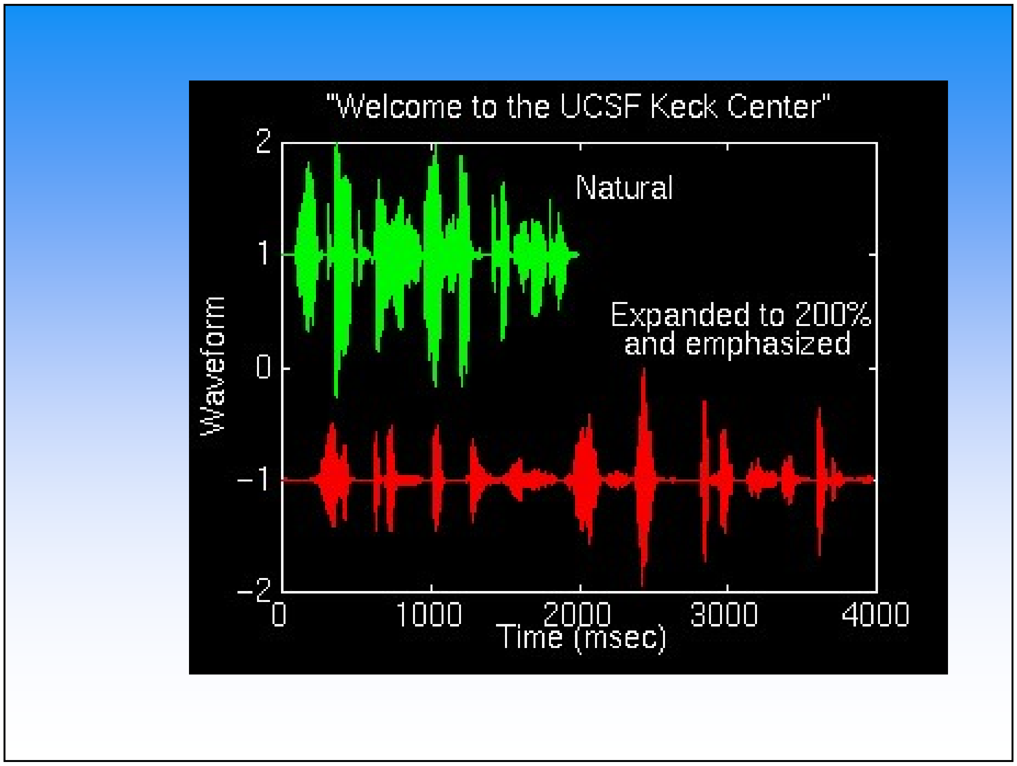
- **The goal of this exercise is to detect whether the two tones are both rising, both falling, or rising and falling**
- **As training progresses the rate of presentation speeds up**

Our first approach was to adapted the Tallal Repetition Test into a **training** method. For the two tone stimuli we developed two **computerized sweep tones,** designed to mimic the acoustic changes within formant transitions. In this computer game, children were trained to press the triangle for one sweep tone and the square for the other. Each child began with two relatively long sweep tones, presented sequentially, with silent intervals that were **long enough** for them to respond correctly about 80% of the time (play 1st one). Successful trials were rewarded and followed by sequences with **slightly shorter** duration sweeps and silent gaps, while errors were corrected. The goal was, **through intensive experience and practice,** to train children to process tone sequences **at faster and faster rates** until they reach the rates that are important for processing speech (play 2nd).

Speech can be computer modified to extend in time the duration of formant transitions

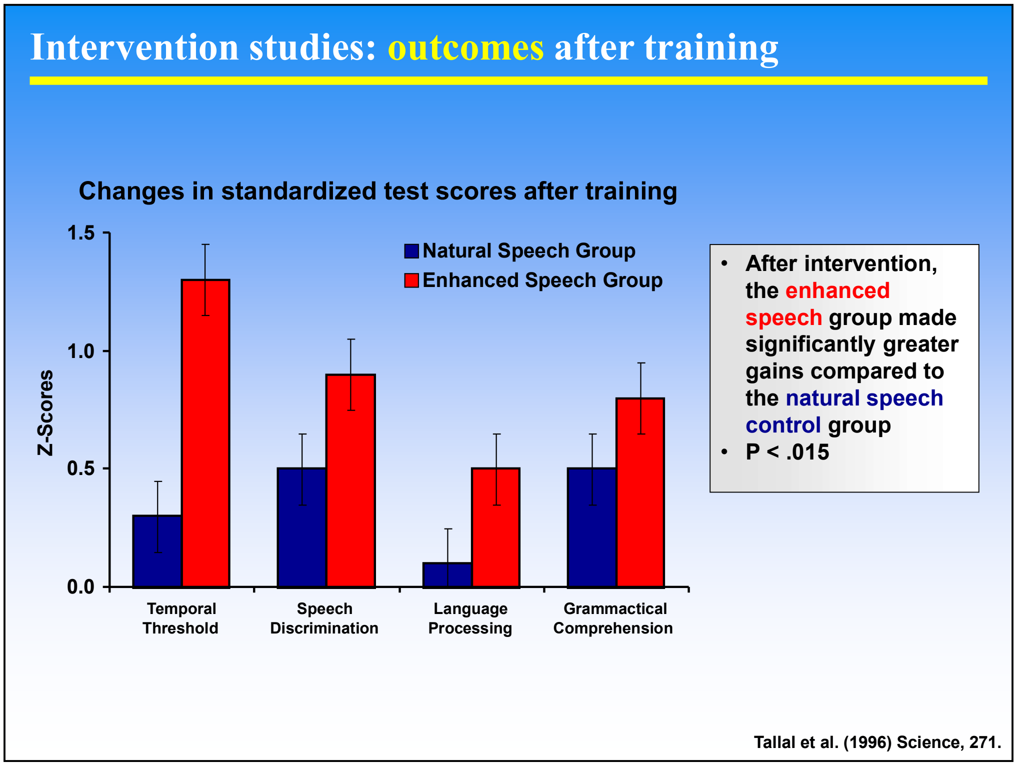


Recall that earlier I had demonstrated that speech perception of individual syllables could be dramatically improved by **extending the duration** of the formant transitions in syllables from 40 to 80 ms..
This discovery was used as the basis of our second approach.



My early research showed that we can correct blurry phonological representations by enhancing and exaggerating the acoustic cues WITHIN speech sounds that DIFFERENTIATE them and allow them to be clearly and distinctly represented in the brain. Our second approach was to develop a speech processing algorithm that extends in time and amplitude enhances the fastest changing acoustic components in the acoustic waveform of ongoing speech. One of the most unique things about Fast ForWord training is that the speech and language exercises begin with this computer modified (enhanced) speech. As the individual progresses in the linguistic training, the amount of acoustic modification (exaggeration) is decreased. The goal is to have each student end up being able to process language at the phonological, morphological, semantic and syntactic level, using normal, fast speech.

Using this approach Fast ForWord focuses on sharpening phonological representation as well as enhancing spoken language abilities at the morphological and syntactic level.



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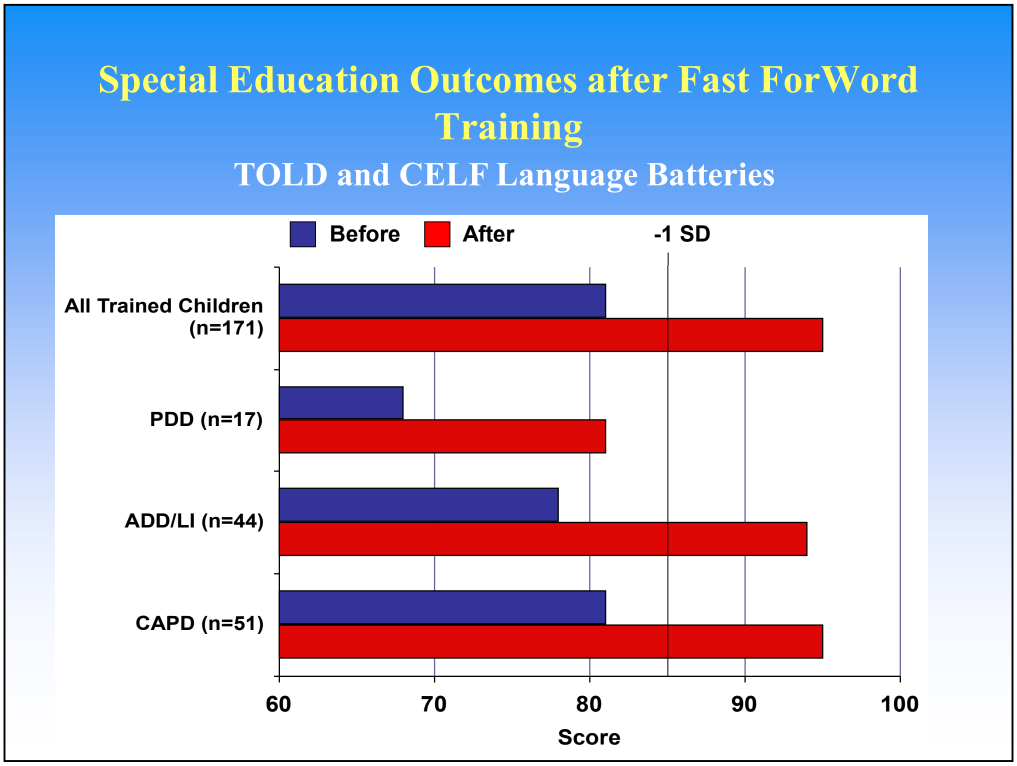
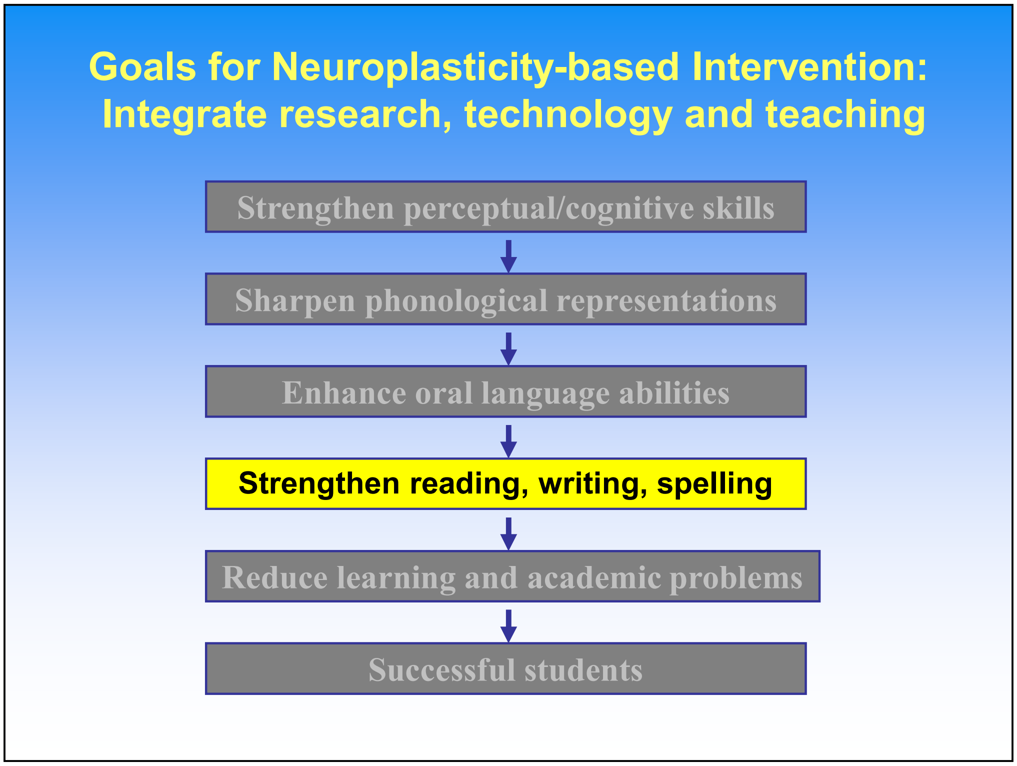
In a controlled study, two groups of LI children, initially match in age and degree of language impairment, were provided the training **daily for 4 weeks**, either **with** or **without** the computer **enhanced speech and RAP training.** Results showed

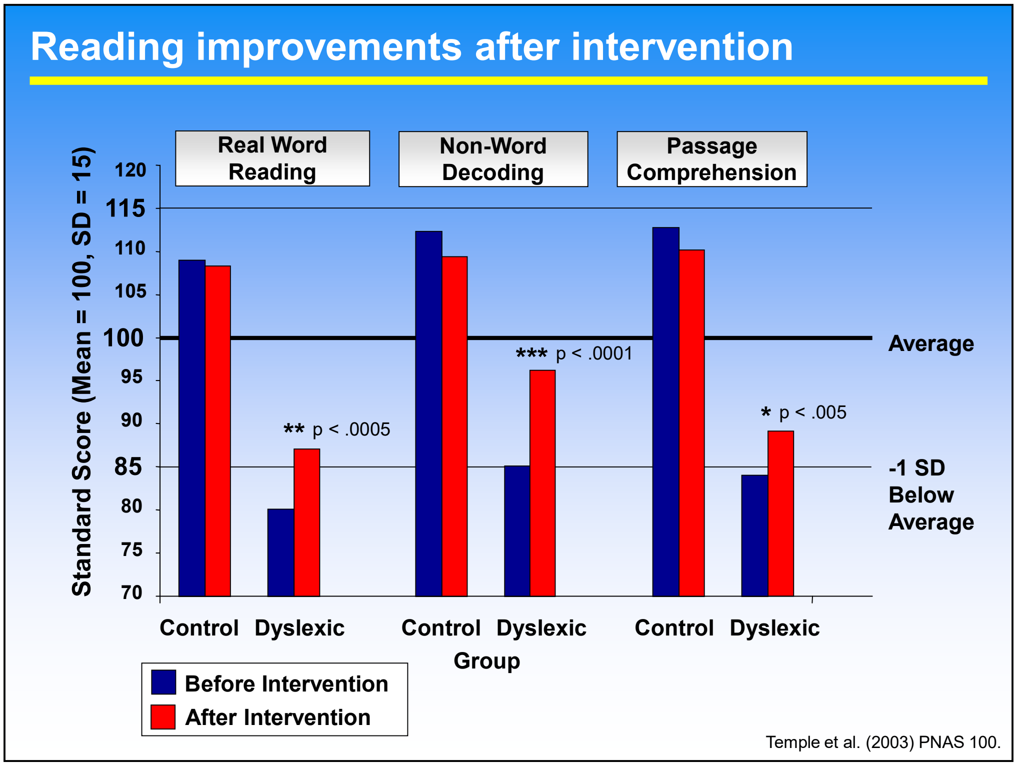
•First, that individual differences in RAP thresholds **could be significantly improved** with training (red bars). This was the first study with children to show that **a basic psychophysical threshold** could be **significantly modified** with **neuroplasticity-based behavioral training**.

• Results also showed that SLI children who received the training **with the computer enhanced speech and RAP training** (red bars**),** made significantly **greater gains** compared to SLI children who received the **same** linguistic training, but with **natural speech (**blue bars**)**, on standardized clinical tests of speech discrimination, language processing and grammatical comprehension.



Clinical field trials conducted by speech pathologists in their own clinics showed that Fast ForWord was effective in significantly improving language outcomes in children with Autism, Attention Deficits and Central Auditory Processing Disorders.


Goals for Neuroplasticity-based Intervention:
Integrate research, technology and teaching
Strengthen perceptual/cognitive skills
Sharpen phonological representations
Enhance oral language abilities
Strengthen reading, writing, spelling
Reduce learning and academic problems
Successful students



This slide summarizes some results for controlled laboratory Fast ForWord studies with Dyslexic Children.

The behavioral effects of training are summarized here.

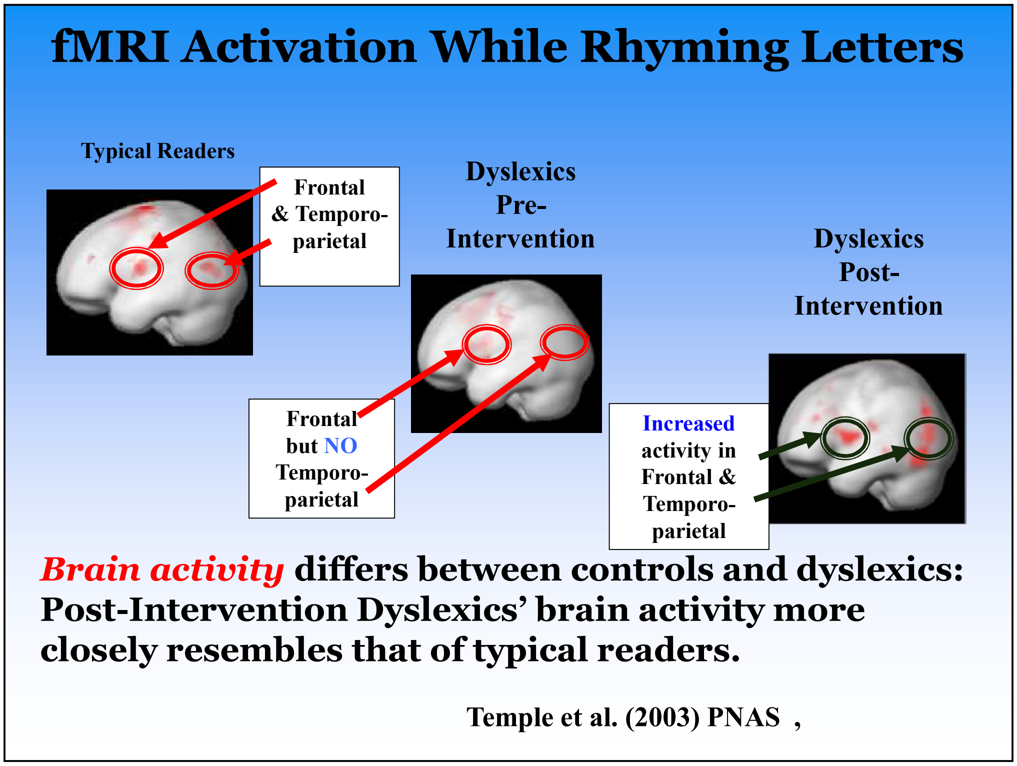
the results from 3 reading tests - real word reading, nonword decoding, and passage comprehension are shown.

On the x axis is group normal and dyslexic reader for each test - and on the y axis is standard score - 100 - where the black dotted line is the standardized mean

and these red lines above and below it represents 1 SD above and below the mean

The Typicall Readers - Control - did not undergo any training, but simply were tested 2 times about 8 weeks apart and, as expected, had no significant change in their scores in such a short time.

However, during the same period of time for all 3 tests, the dyslexic children - as a group - showed a significant improvement after training, despite the fact that no direct reading instruction was provided, and no letters or written words were used in this training.



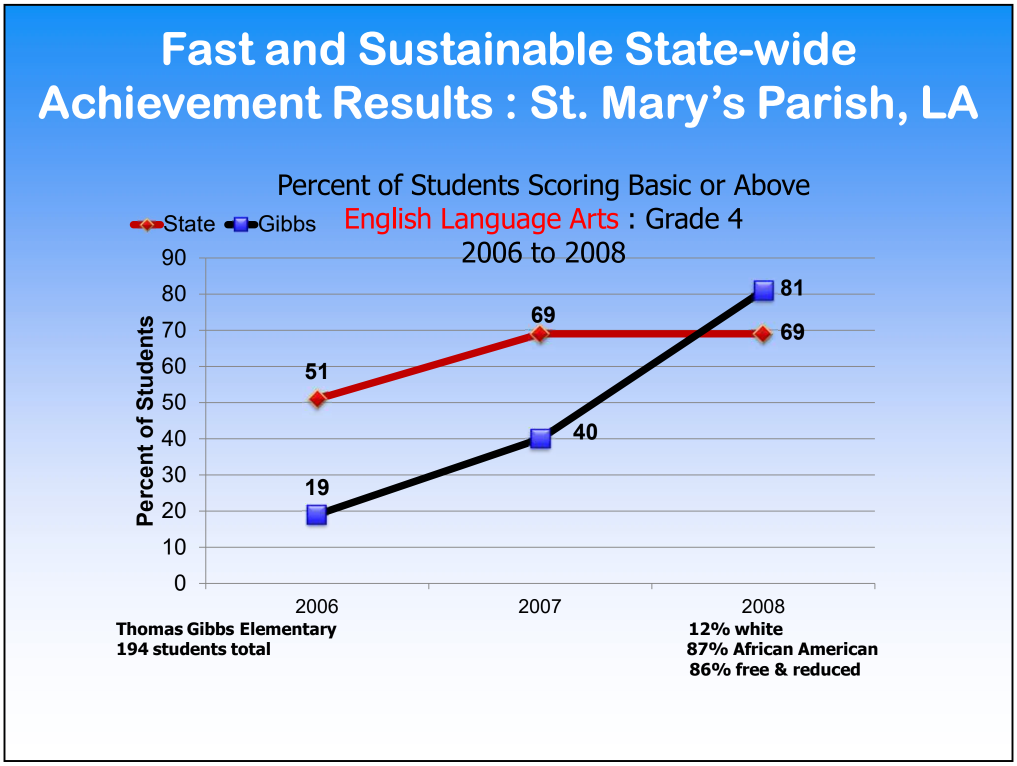
Subsequent studies using Fast ForWord, done at Stanford and Harvard, replicated these behavioral results with Dyslexic children, while also extending them by adding fMRI scanning.

fMRI scans done before Fast For Word training showed that when doing a **rhyming letters** task, typical readers show frontal and temporoparietal brain activation, while Dyslexic children show weak frontal and **no** temporoparietal activation.

After only 8 weeks of Fast ForWord training, the Dyslexics' **brain activity** was significantly **increased**, so that it more closely resembles that of typical readers, in both the frontal and temporo-parietal brain regions important for language and reading,

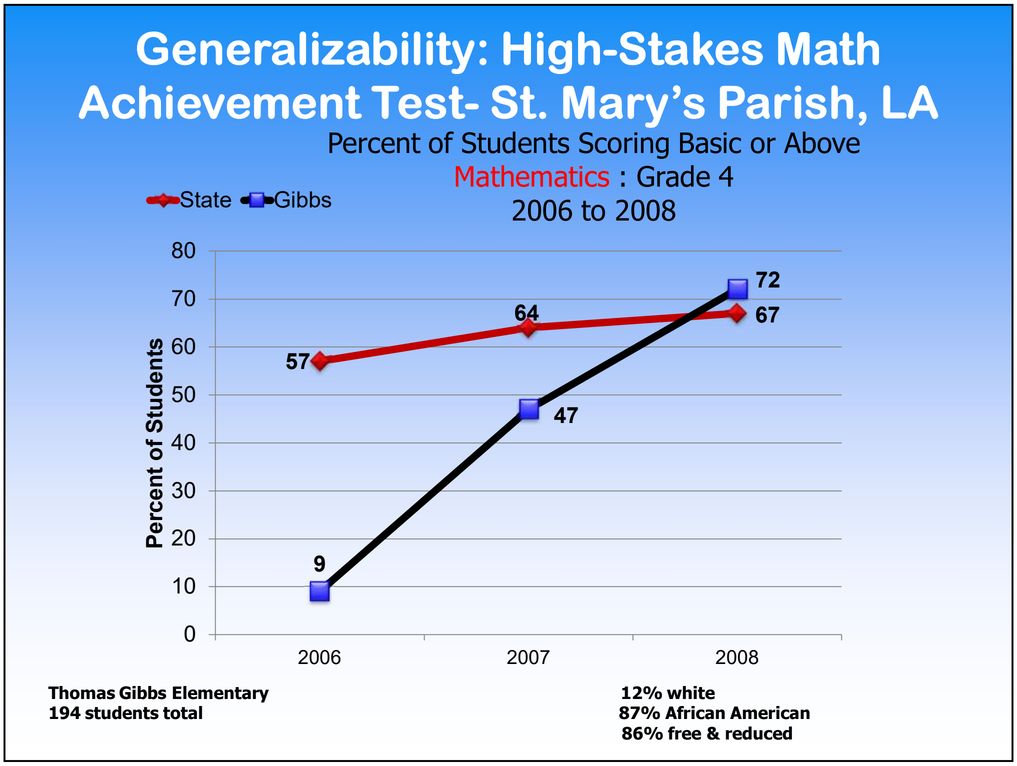
Fast ForWord has subsequently been expanded to include explicit reading programs that increase in difficulty from Reading level 1 – 5.. Fast ForWord Reading explicitly train essential components of literacy skills at the phonological, morphological, syntax and grammatical levels using the neuroplasticity-based approach while simultaneously continuing to incorporate sequencing, attention and memory training.

The complete family of Fast ForWord language and Reading programs have been implemented in thousands of schools in the US and around the world.



Many large scale, real-world studies have been conducted in schools and clinics around the world.

Here I show the results of a longitudinal study conducted at a struggling public elementary school in LA with a predominantly low income, minority population of students. 194 students from Gibbs Elementary school began using the Fast ForWord- Language and Reading programs in 2006. At that time only 19 percent of these students scored at basic or above in English Language Arts on the LA state-wide achievement test as compared to the state-wide average of 51 % who scored in this range. This longitudinal study shows the progress of Gibbs students over the two years that they used Fast ForWord programs, increasing from 19 % to 81 % of their students scoring basic or above ..



It is important to recall that 80% of classroom instruction, even in subjects such as math, is spoken language. Language abilities has been shown to be highly correlated with math abilities. This suggests that improving perceptual/cognitive building blocks for learning coupled with linguistic training should generalize to math improvement, even in the absence of additional explicit math content instruction. This graph demonstrates dramatic improvement in math high-stakes achievement test scores after using Fast ForWord language and reading programs. Over the two -year period of this study, the percent of students scoring basic or above in math increased from only 9 % to 72%.

What is Unique about Neuroplasticity-base Training Using Fast ForWord

1) F A S T, efficient, cost-effective
2) Sustainable
3) Builds the neural foundation upon which all proficient learning depends

To date, over 3 million children in 55 countries internationally, have received Fast ForWord® Language and Reading intervention programs.

Panel Discussion & Questions

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ite Performance Solutions provides our software and
rvices through our partners:

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hank you again for joining us!

oin us again next month (April 20/21) for,

Building Better Brains

with Henry Mahncke Ph.D.

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