



TEXAS CENTER  
*for*  
LEARNING  
DISABILITIES

# Neuropsychology of Learning Disabilities: An Interdisciplinary Perspective

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Presidential Address  
International Neuropsychological  
Society  
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Texas Center for Learning  
Disabilities (NICHD P50  
HD052117)

## Reading for SUCCESS

The Texas Center for  
Learning Disabilities  
(TCLD) investigates  
the classification,  
early intervention,  
and remediation of  
learning disabilities.



# Neurogenetic Disorders of Childhood

## **Congenital**

- PKU
- Downs Syndrome
- Fragile X
- Spina Bifida
- Turners Syndrome
- Williams Syndrome
- Velocardiofacial Syndrome

## **Developmental**

- Learning Disabilities
- ADHD



# Genes, Brain, and Behavior

- Rapid advances in scientific understanding in all domains
- Interdisciplinary, international collaborations- Not parallel play
- Advances in one domain fuel another domain
- Neuropsychologists have a long tradition of working at the edges of disciplinary boundaries and talking about LD for Presidential addresses



## Learning Disabilities :Major Shifts in Scientific Understanding

- Early views “of constitutional origin” (bad gene-bad brain) have shifted to interactions of genes, brains, and environments
- Prominent view instantiated in public policy: discrepancies in IQ and achievement as a marker for unexpected underachievement
- Classification research showed limited validity; focus on academic deficits as necessary but not sufficient for identification



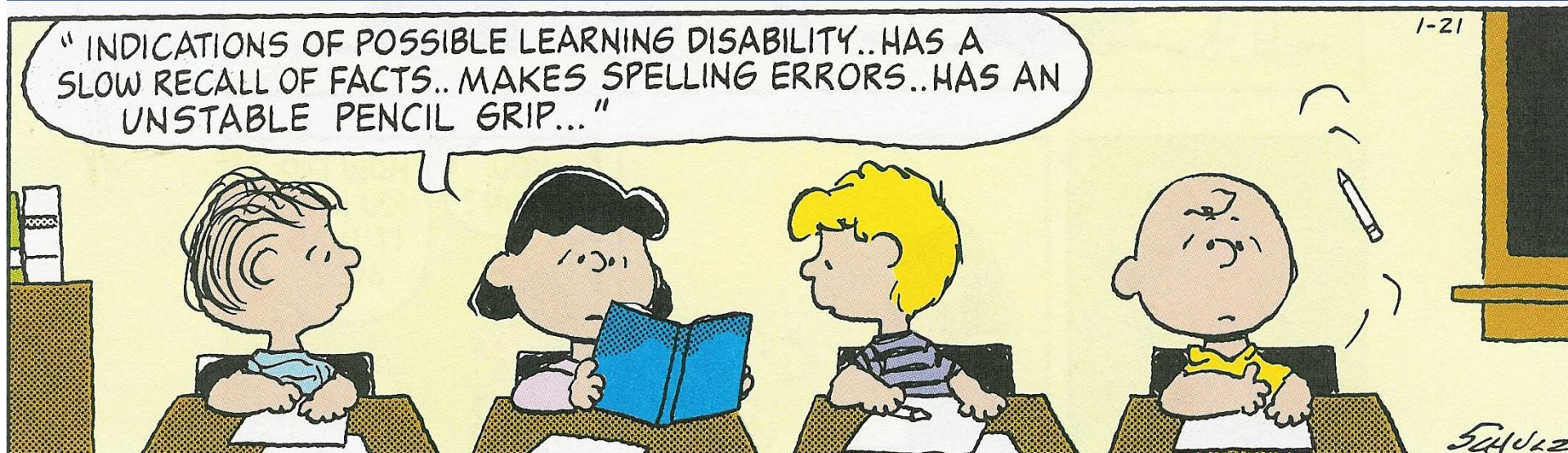
## Learning Disabilities :Major Shifts in Scientific Understanding

- Progress in understanding cognitive mechanisms underlying different academic skills, esp. reading
- Greater understanding of appropriate samples for neurobiological studies (began to study same kinds of children), fueling **interdisciplinary** approaches
- Emergence of noninvasive technologies for brain imaging and application of modern genetic methods to large samples of LD focusing on academic deficits
- Intervention studies take advantage of the emerging research base. Many children poorly taught (add **intractability** to identification)



FROM "PEANUTS"

# What is a Learning Disability?



Is Charlie Brown LD? 1968 View of LD as a constitutional disorder of psychological processes...





# 1968 US Federal Definition

The term “specific learning disability” means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may **manifest** itself in **an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations**. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning disabilities which are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or of environmental, cultural, or economic disadvantage.

**(USOE, 1968)**



# I. Concept of Cerebral Dysfunction

- Still (1902): Disorder of Morbid Control
- Kahn and Cohen (1925): Organic Drivenness Syndrome
- Strauss and Lehtinen (1948): Minimal Brain Injury
- Bender (1952): Bender Gestalt
- Easter Seals/NINDS (1962): Minimal Brain Dysfunction
- Dept of Education (1968): Specific Learning Disabilities
- DSM III (1980): Academic Skills Disorders, ADHD





## II. Concept of Dyslexia/LD

- Hinshelwood, Morgan, others (1896): congenital word blindness- disorder of left angular gyrus
- Orton (1925): strephosymbolia (dyslexia)- disorder of hemispheric organization (cerebral dominance)
- Kirk (1963): Specific Learning Disabilities (constitutional origin)
- Dept of Education (1968): Specific Learning Disabilities



# Neuropsychological Approaches to LD: Historical Focus 1

- Neuropsychological models focused on domains beyond academic skills because of the interest in brain dysfunction
- Poor academics another sign-not the main focus of the research question
- Understanding the academic problem does not explain the problem at the level of the brain
- Treatment stems from an understanding of brain dysfunction



## Neuropsychological Correlates of Reading Disability. "Defects" in...

- Visuoperception (spatial processing)
- Directional sense (right-left discrimination)
- Audioperception (speech sound discrimination)
- Intersensory integration (matching auditory and visual input)
- Oral language (generalized language disorder)
- Sequencing and finger recognition
- Cerebral dominance (hand preference)
- CNS function (associated motor disorders)

Benton, 1975



# Neuropsychological Theories of Reading Disability

- Focal Maldevelopment: Angular Gyrus, Incomplete Parietal Lobe Development
- Disturbance of Brain Organization: Cerebral Dominance (Orton)
- Some Models Imply Particular View of Reading Process: Disconnection Syndrome (Color Naming; Geschwind), Intersensory Integration; Birch)

Benton, 1975



## Benton, 1975

“...a neurological basis for developmental dyslexia has not been established, the empirical evidence...inconsistent and circumstantial.” (highlighted relevance of parietal lobes)

“One striking deficiency...is the failure to provide an adequate description of the behavioral disability.”

“Continued investigation of dyslexia as an expression of more basic linguistic disability is also indicated.”



## Neuropsychological Theories of Learning Disability: Historical Focus 2

- Children are heterogeneous
- Search for subtypes based on patterns of NP strengths and weaknesses
- Focused on minor signs and correlates
- Subtypes should reflect more homogeneous groups associated with distinct etiologies



## Neuropsychological Theories of Learning Disability: Strengths

- Identified CNS factors as fundamental cause of LD
- Recognized the need to address the heterogeneity of LD
- Identified precursors of LD that could form the basis for screening
- Evaluated many skills and abilities associated with LD





# Neuropsychological Approaches to LD: Problems

- Focus on tests, not constructs
- Stem from an interest in etiology as a precursor to treatment
- Don't link closely to knowledge base on the development of academic skills
- Don't lead to effective intervention (little evidence that focus on minor signs, correlated deficits, or cognitive processes generalizes to improved reading, math, or writing)



# Neuropsychological Theories of Learning Disability: Problems

- **Major problem:** Imposition of clinical model of assessment onto a common set of difficulties that impact adaptive functioning in relatively narrow contexts (components of school, work)
- **Clash of models:** Academic vs. Brain Function
- Most reliable subtypes at the level of academic skills
- How can LD be explained if the academic component is not central?

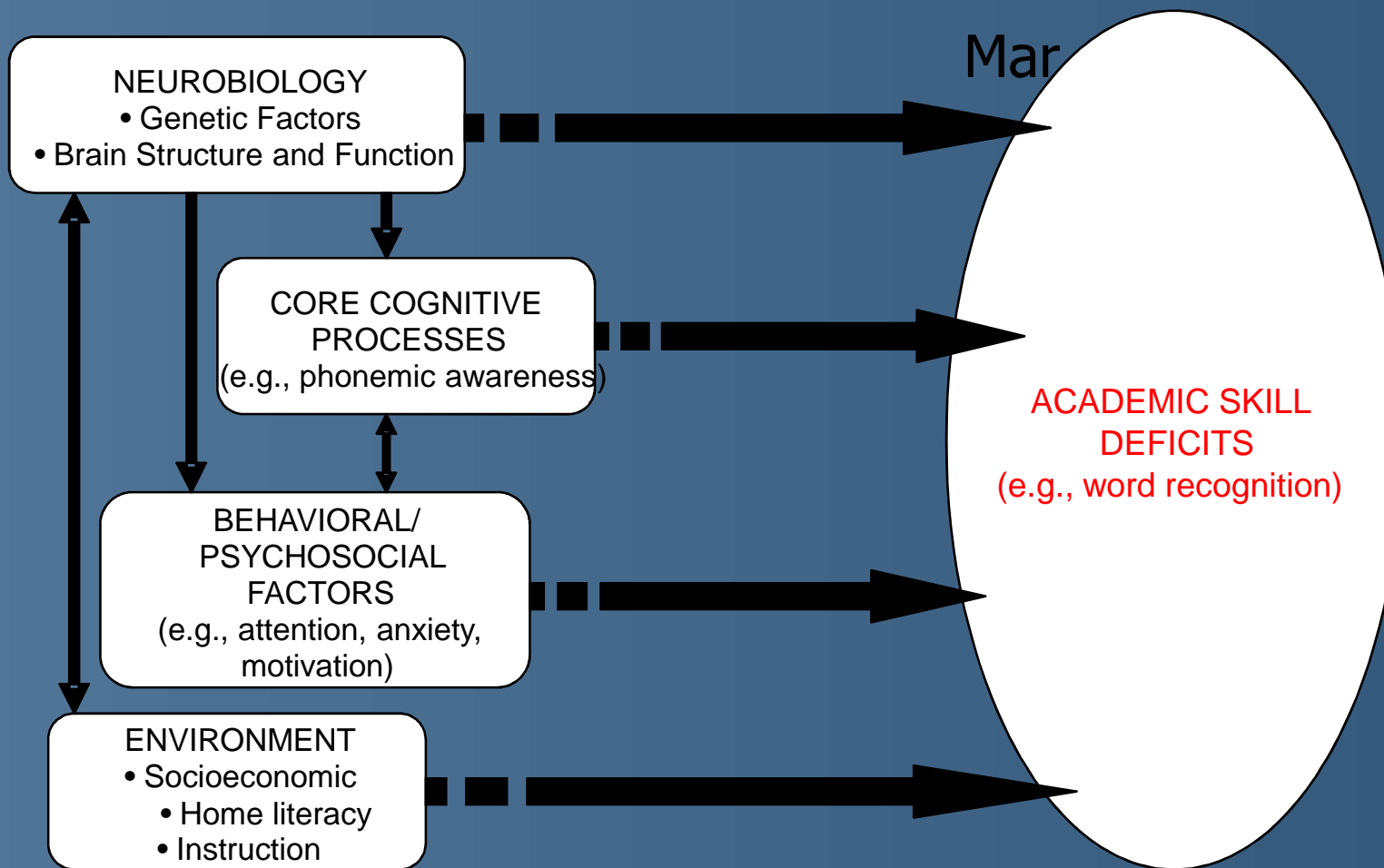


# Neuropsychological Theories of Learning Disabilities: Progress

- Work across disciplines
- Abandon exclusionary definitions- look for identification criteria that are inclusionary and systematically address sampling issues
- Integrate cognitive theory on academic skills development- language and reading- with research on genes and brains
- NICHD- LD initiative (1980's)- definition and classification, cognitive correlates, neurobiological factors, intervention fueled an international, interdisciplinary effort



# A Comprehensive Model of LD (Fletcher, Lyon et al., 2007)





## 1977 Federal Regulatory Definition is a Classification Hypothesis

**A severe discrepancy between achievement and intellectual ability** in one or more of the areas: (1) oral expression; (2) listening comprehension; (3) written expression; (4) basic reading skill; (5) reading comprehension; (6) mathematics calculation; or (7) mathematic reasoning. The child may not be identified as having a specific learning disability if the discrepancy between ability and achievement is primarily the result of: (1) a visual, hearing, or motor handicap; (2) mental retardation; (3) emotional disturbance; or (4) environmental, cultural, or economic disadvantage (USOE, 1977).



# DSM-IV Criteria

- A. Reading achievement, as defined by standardized achievement tests of **reading accuracy or comprehension**, is substantially below that expected given the person's **chronological age, IQ, and age-appropriate education**
- B. The disturbance in criterion a substantially interferes with academic skills or activities of daily living that require reading
- C. If a sensory deficit is apparent, the reading difficulties are in excess of those usually associated with it



# ICD- 10 Criteria

- A. (1) a score on **reading accuracy and/or comprehension** that is at least **2 standard errors** of prediction below the level expected on the basis of the child's chronological **age** and **general intelligence**
- (2) a history of serious reading difficulties, or test scores that met criterion A (1) at an earlier age, plus a score on a spelling test that is at least 2 standard errors of prediction below the level expected on the basis of the child's chronological age and IQ.

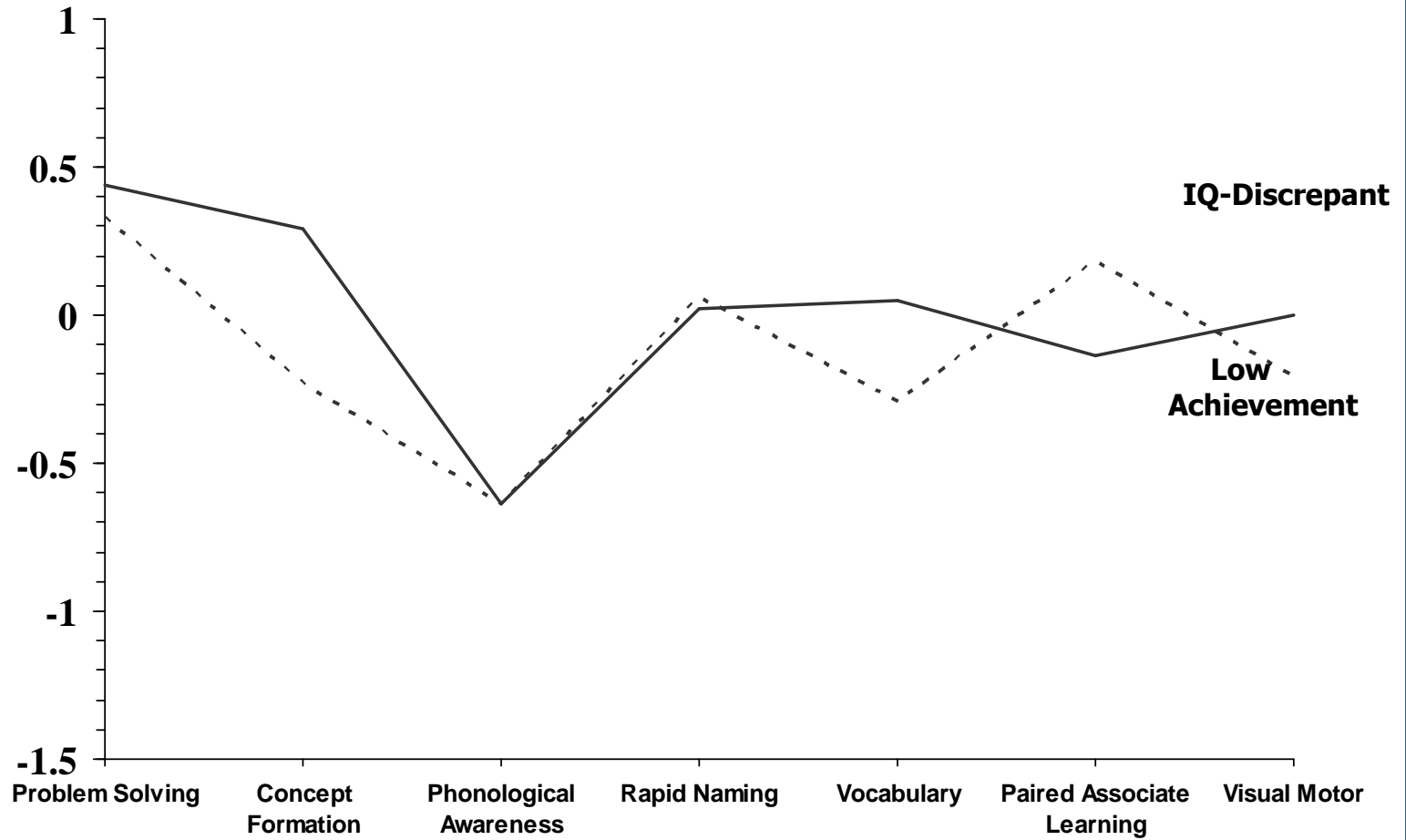




# Fletcher et al., 1994

Age Adjusted Standardized Score

## RD Groups





# Learning Disabilities are Dimensional Constructs

- All disabilities have biological and social realities that vary with “disorder” and “person”
- Epidemiological studies in New Zealand, United Kingdom, US: Learning disabilities are dimensional- variation on normal development
- Model is obesity or hypertension, not measles and mumps
- Measurement error and cut point are huge problems- children close to cut point are more similar than different (**it's a continuum**)
- Same theory explains success and failure (☺)



# Low Achievement is Necessary but Not Sufficient

- Homogeneity is at the level of the academic skill
- Processing subtypes duplicate academic subtypes because they are correlated deficits and don't explain independent variability
- Define academic subgroups based on inherently arbitrary criteria tied to a dimension
- Leads to coherent classification that is reliable and valid
- Simplifies identification process; fueled research in other domains
- Now we need to add intractability



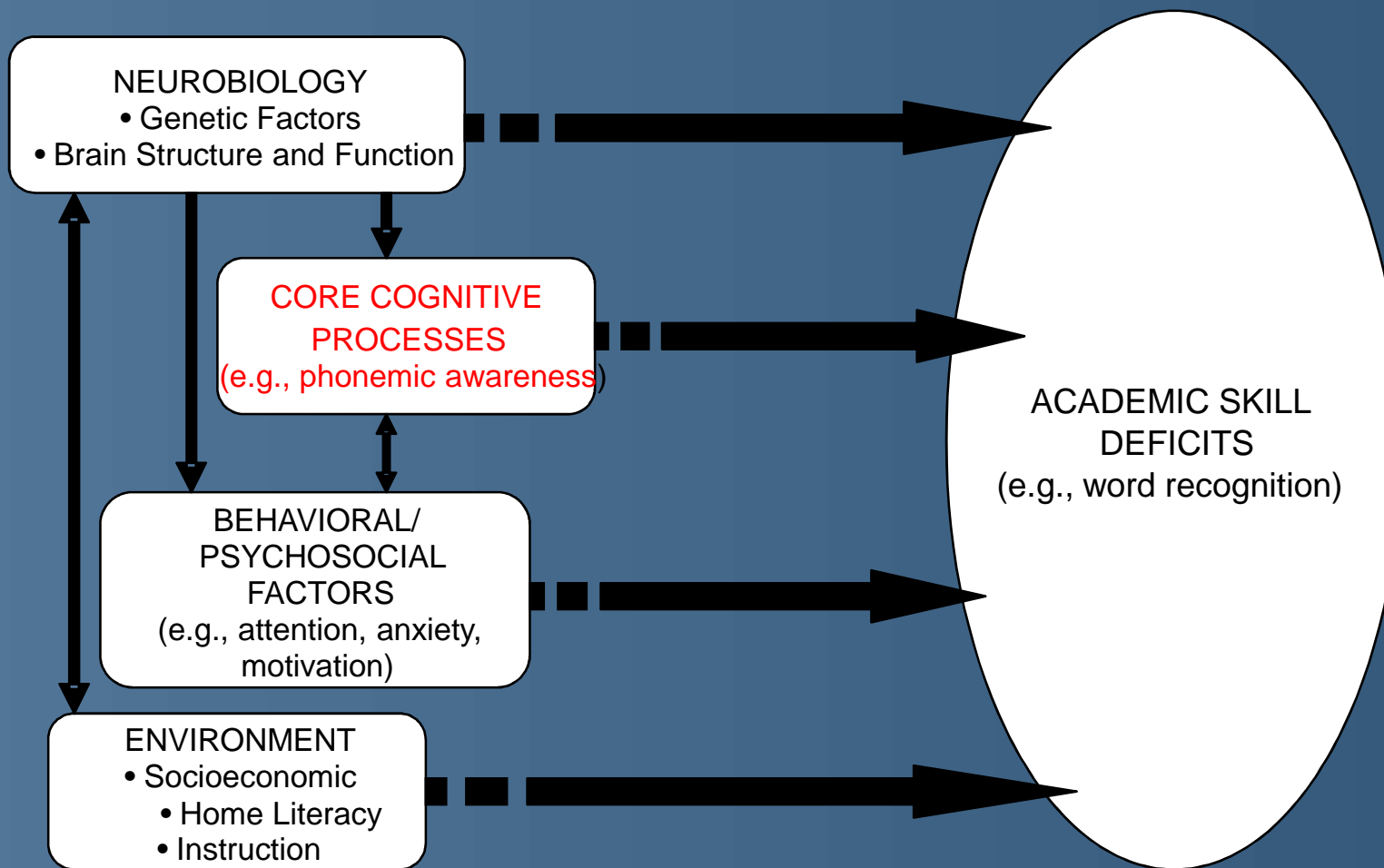
## Hypothetical Classification of LD: Marker Variables involving:

- 1. Word Recognition (Dyslexia)
- 2. Reading Fluency
- 3. Reading Comprehension
- 4. Math Computations (Dyscalculia)
- 5. Math Problem Solving
- 6. Written Expression (Handwriting, Spelling, Text Generation?)

Occur in isolation and concurrently, but  
basis for defining samples



# A Comprehensive Model of LD (Fletcher, Lyon et al., 2007)





# Core Cognitive Processes

- Vary with academic domain
- Supports validity of the hypothetical classification
- Do not require assessment for identification, but do represent precursors
- Don't add value to intervention (aptitude X treatment interaction)
- Do help understand neural mechanisms and essential for comprehensive understanding of LD



# A Big Idea in Science: Alphabetic Principle

- Print represents speech through the alphabet; reading is a linguistic skill
- Words are composed of internal units based on sound called “phonemes”
- In learning to read, children must make explicit an implicit understanding that words have internal structures linked to sounds- not a natural process
- Children vary considerably in how easily they master this principle

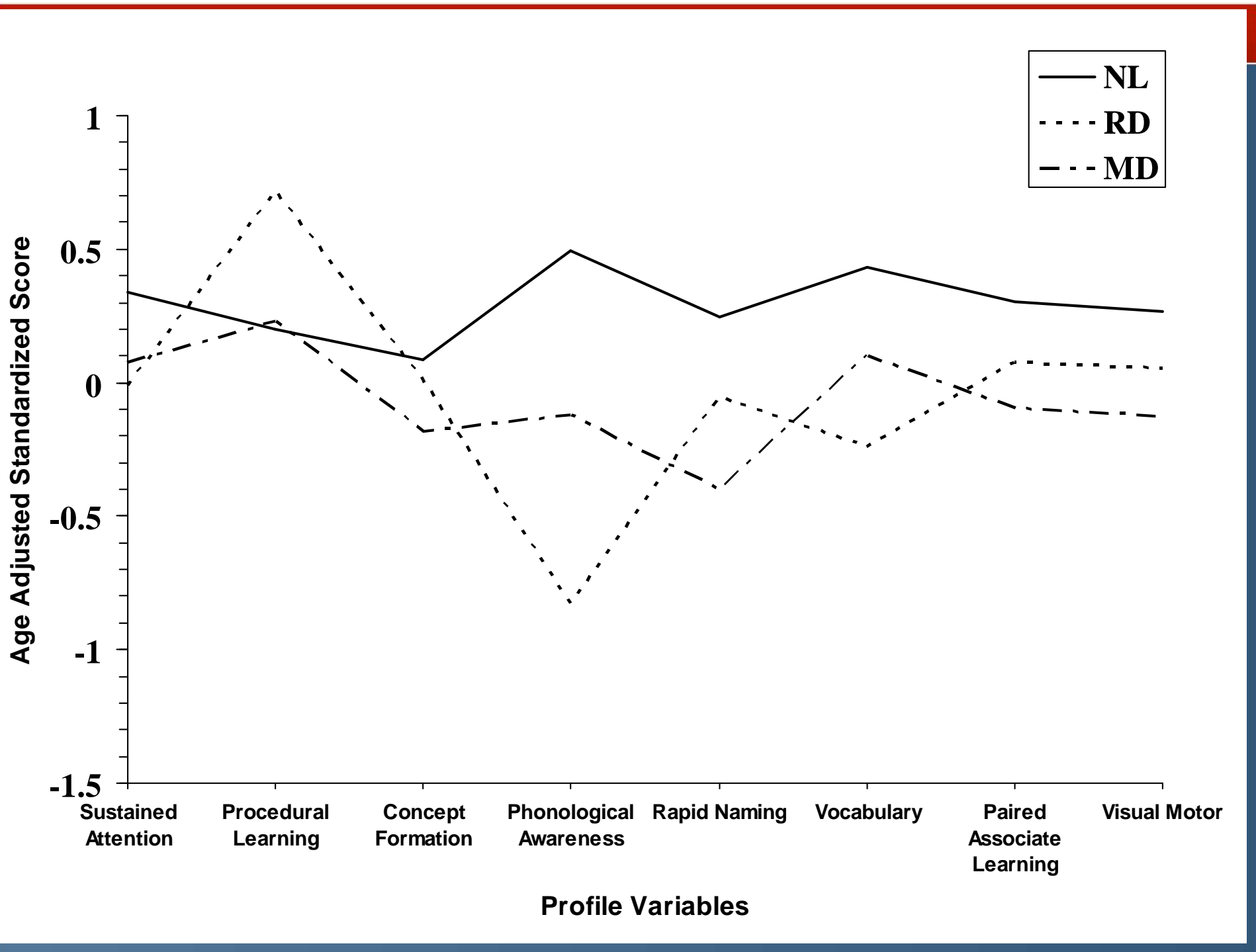




# Neuropsychological Correlates of Dyslexia

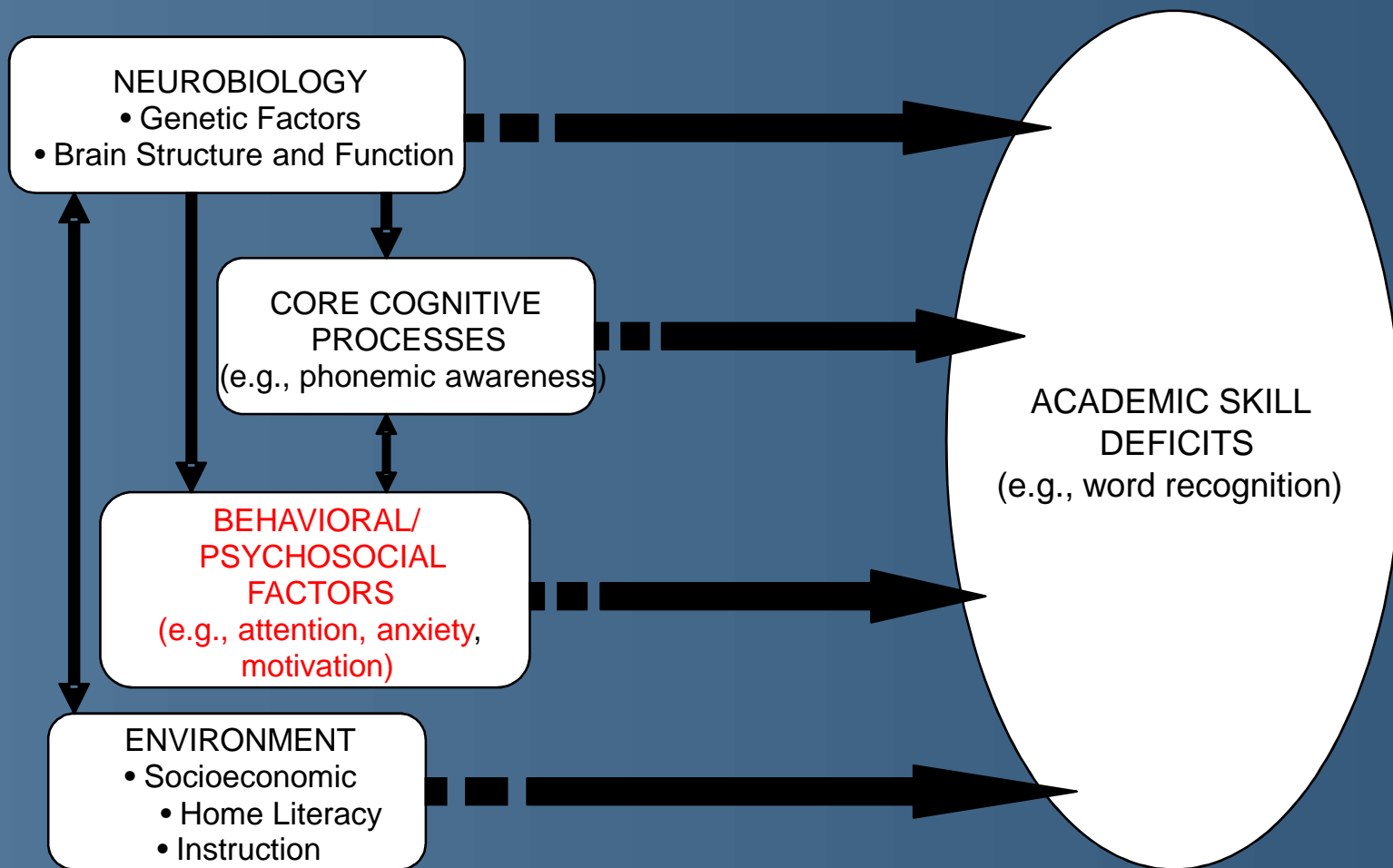
- Phonological Awareness
- Rapid naming
- Verbal Working Memory

**“Tangled web of behavioral research”**  
(Doehring, 1978): children with and without LD differ on virtually every dimension assessed. A univariate difference doesn't validate a hypothesis





# A Comprehensive Model of LD (Fletcher, Lyon et al., 2007)





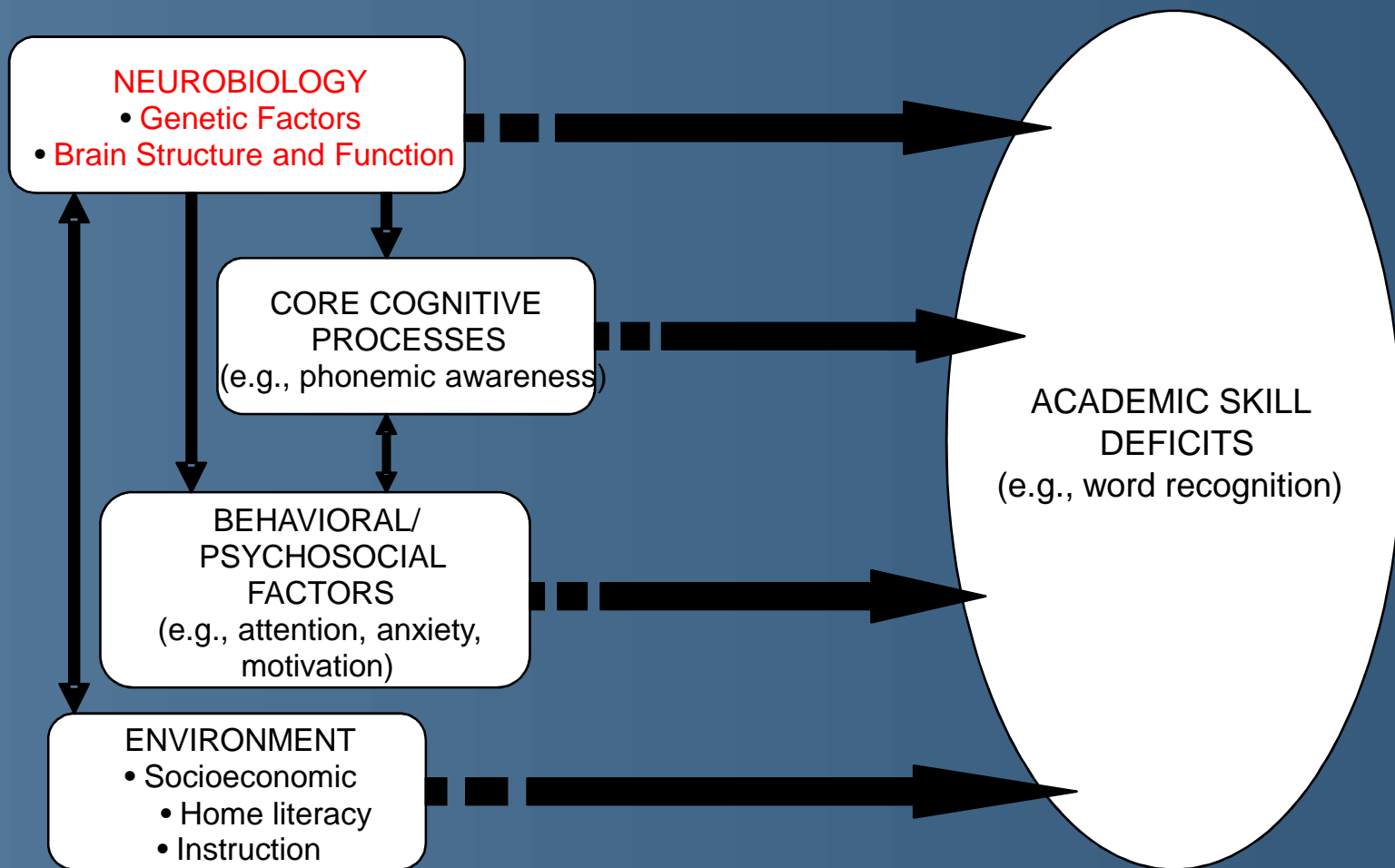
# Behavioral/Psychosocial Factors

- Comorbid associations, especially ADHD
- Experience of failure
- Reaction of peers and family
- Motivation

Major source of heterogeneity in research. Must be assessed in order to plan treatment, but not part of identification.



# A Comprehensive Model of LD (Fletcher, Lyon et al., 2007)





## Brain Structure: Overview

- Brains of children with LD are visibly normal
- Postmortem studies based on small, heterogeneous sample- results not persuasive
- Quantitative structural MRI studies show inconsistent results- most general finding is smaller left temporal lobe (poorly controlled), but multiple structures implicated
- Lots of variables in small samples

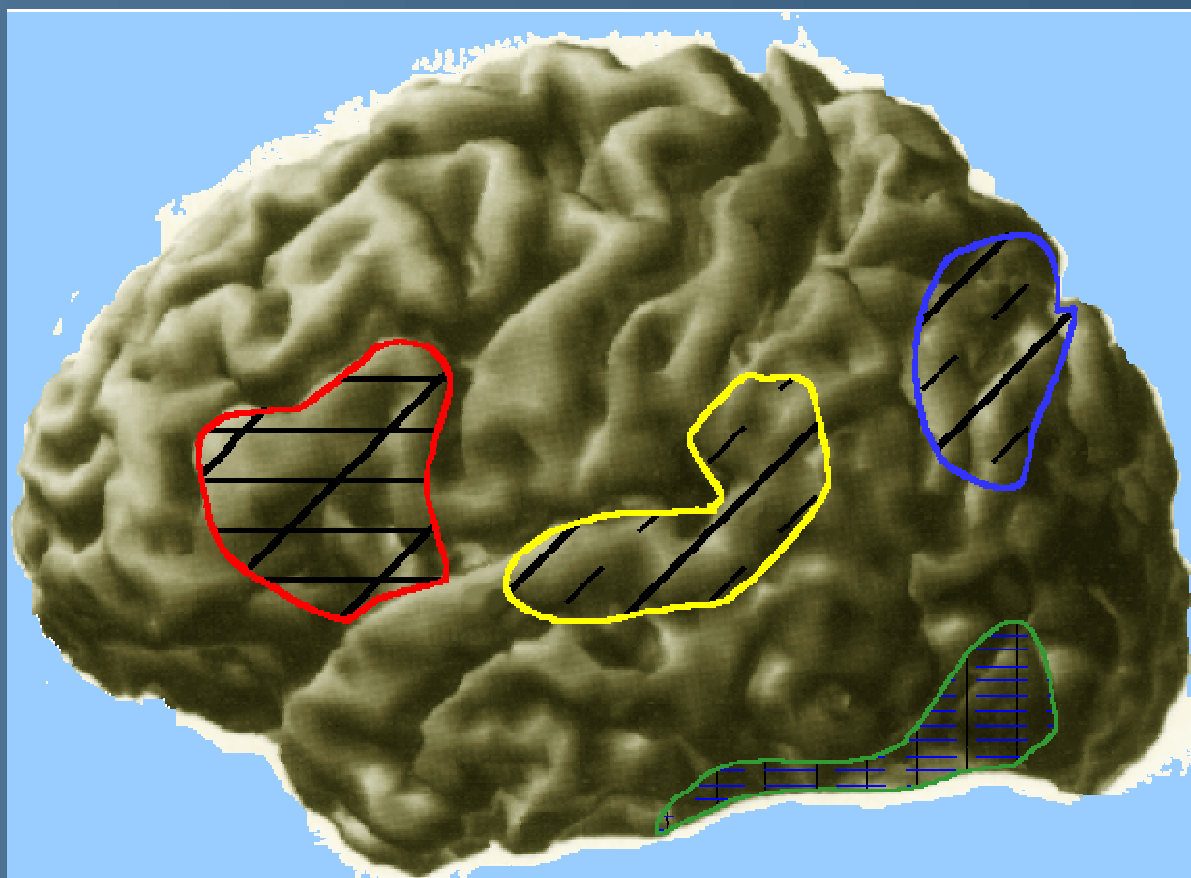


# A Model for the Brain Circuit for Reading (Component Processes)

**Phonological processing:  
correspondence between  
letter and sound**

**Relay station;  
Cross-  
modality  
integration**

**Phonological  
processing:  
articulatory  
mapping**



**Graphemic  
analysis**

Courtesy A. Simos



# Center for Clinical Neuroscience



A.C. Papanicolaou



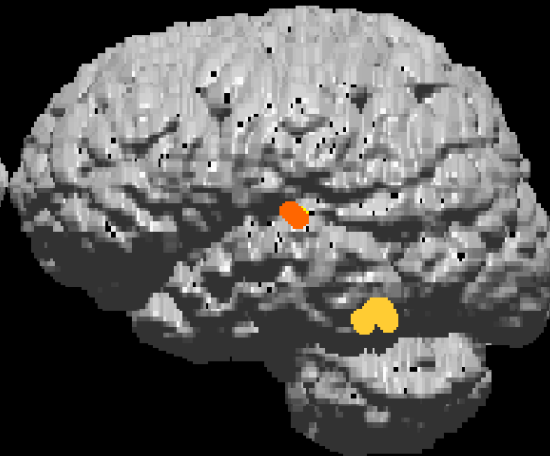
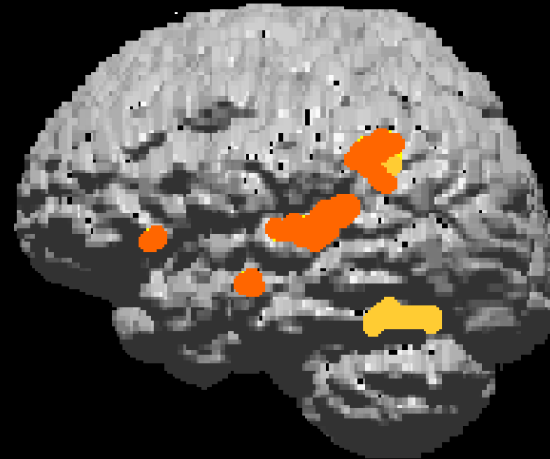
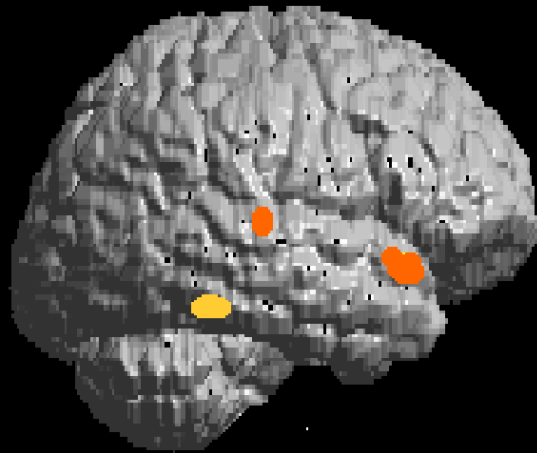
# Brain Function in Dyslexia (Simos et al., 2001)

Child #12: with  
Reading Difficulties

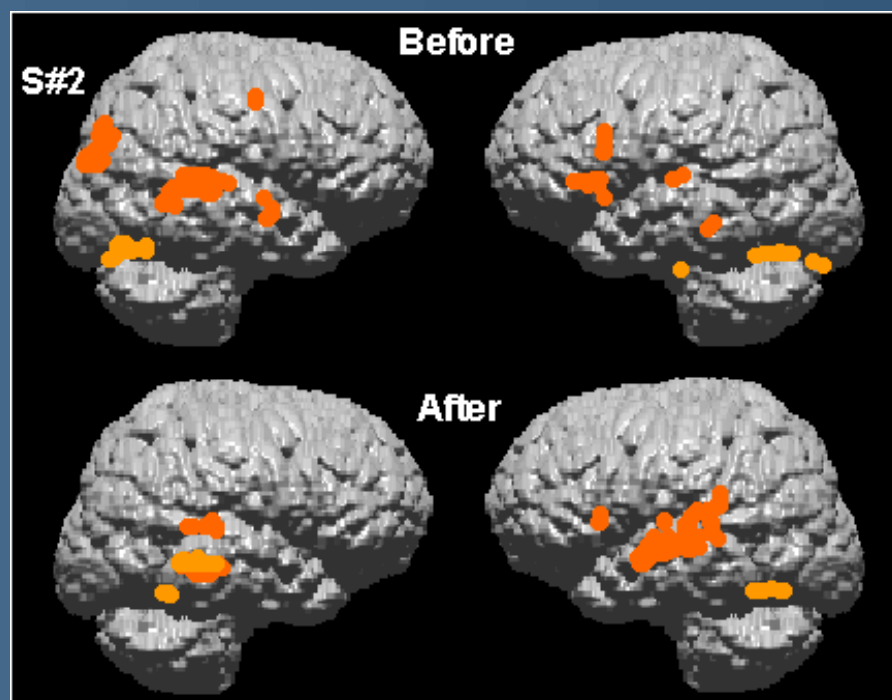
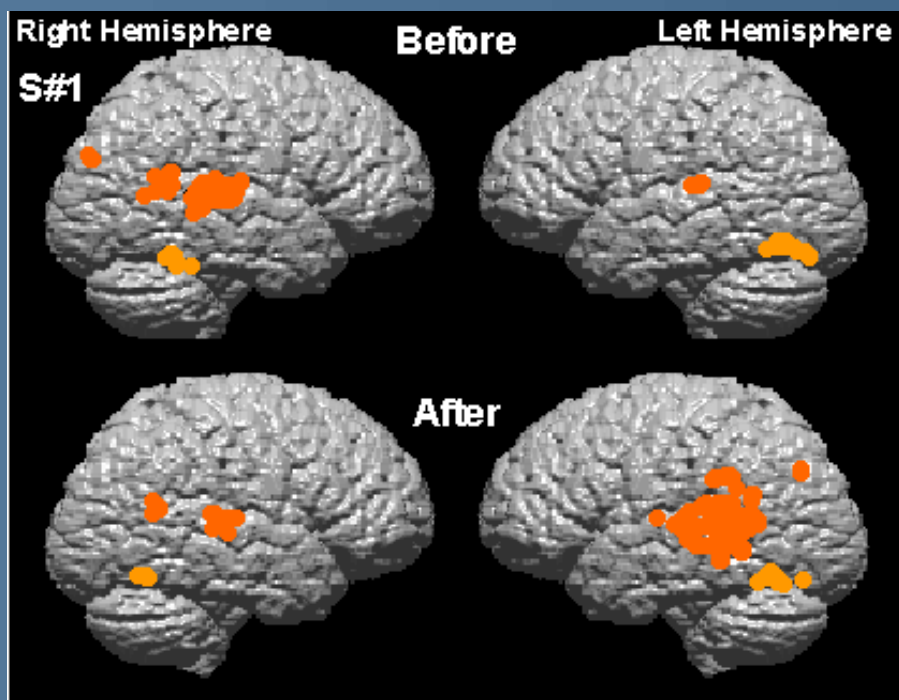
Child #1: Normal Reader

Right Hemisphere

Left Hemisphere

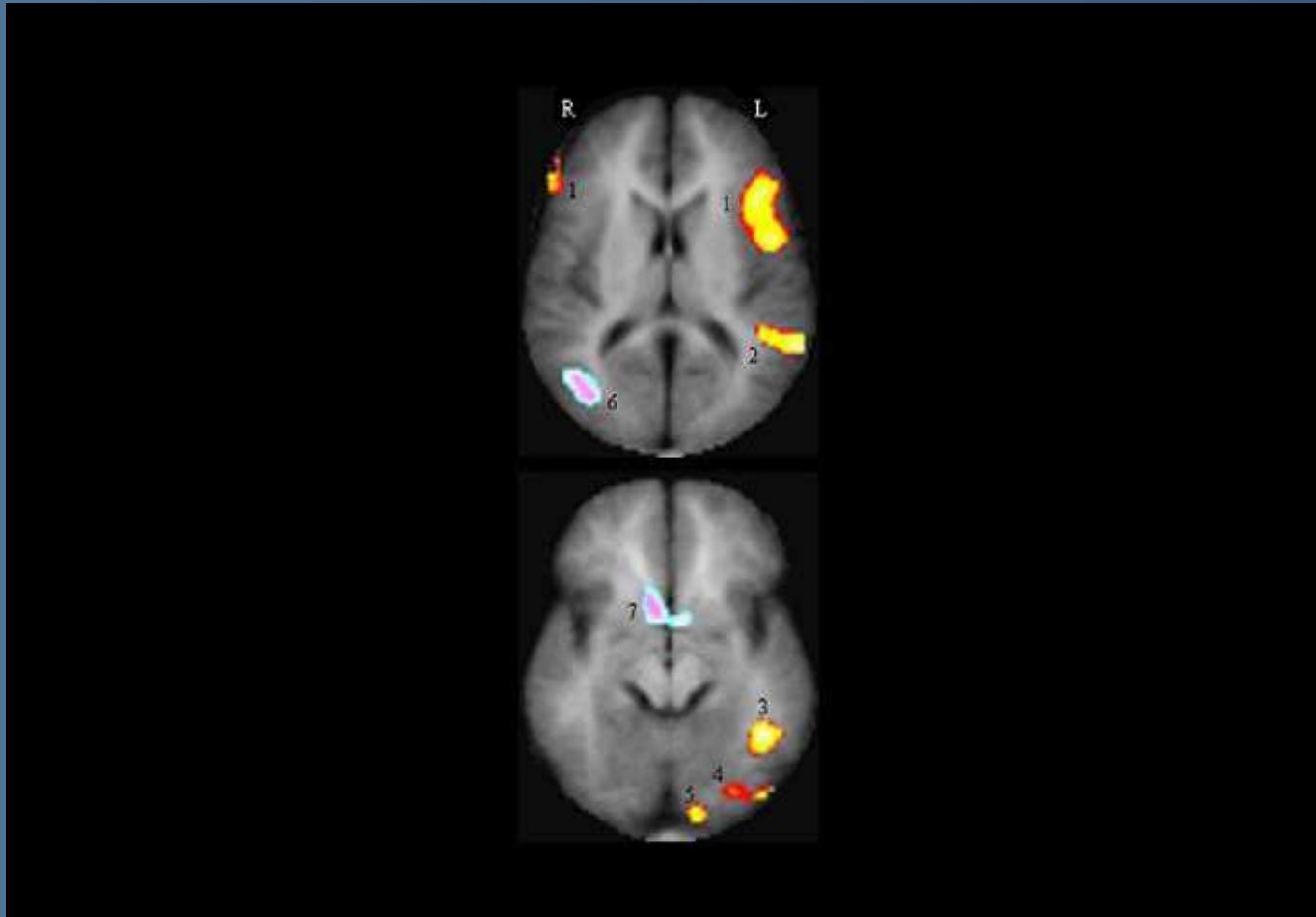


# Neural Response to intervention; (Simos et al., 2002)





# Shaywitz et al., 2004- Biological Psychiatry

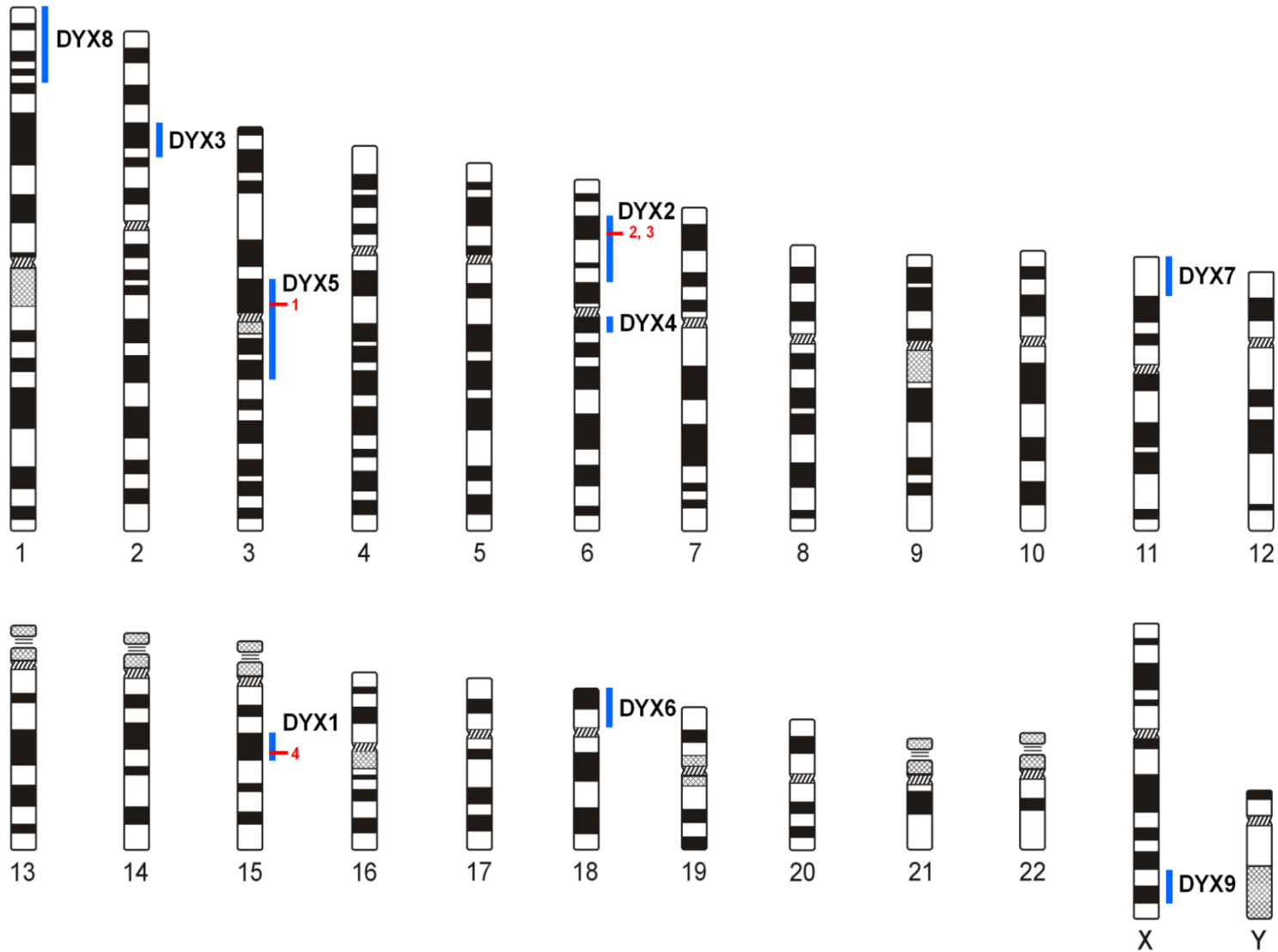




## Genetic Factors

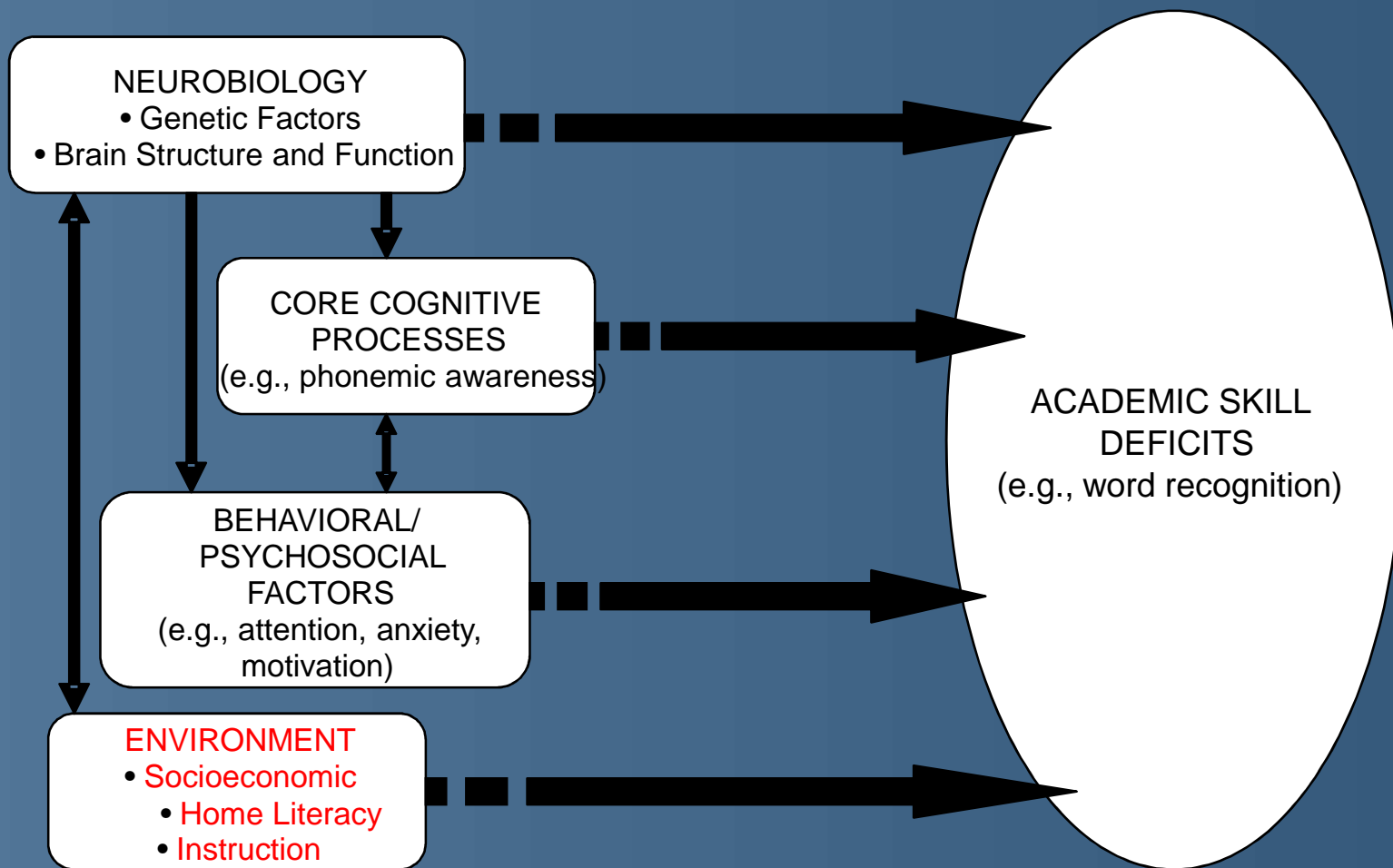
- Benton (1975): runs in families, esp. MZ twins; more males
- Reading, math, and writing are heritable traits; 11 sites, 4 candidate genes for reading/dyslexia
- In reading, heredity accounts for 50-80% of variance in outcomes
- No genes specific to poor development (e.g., no dyslexia genes)
- Genetic organizations (quantitative trait loci) make brains at risk; level of risk is modified by environment, but genetic correlation increases with age

# Where in the genome?





# A Comprehensive Model of LD (Fletcher, Lyon et al., 2007)





# Environmental Factors

- Home environment and quality of language
- Socioeconomic factors: parental education, poverty
- **Instruction**



# Word Reading: Multiple Meta-Analyses

- Lipsey and Wilson (1993) .34 for educational interventions
- Swanson (1999) .57 for word reading in LD
- NRP: .98 K-2; .49 G2-6 for word reading in poor readers
- Similar effects in multiple studies of children identified with word reading problems
- Effects stronger if programs more comprehensive, begin earlier, last longer, in smaller groups with more intensity, and focus on reading; smaller for fluency and comprehension, esp. if remedial





## Mathes et al., 2005: Grade 1 Nonresponders

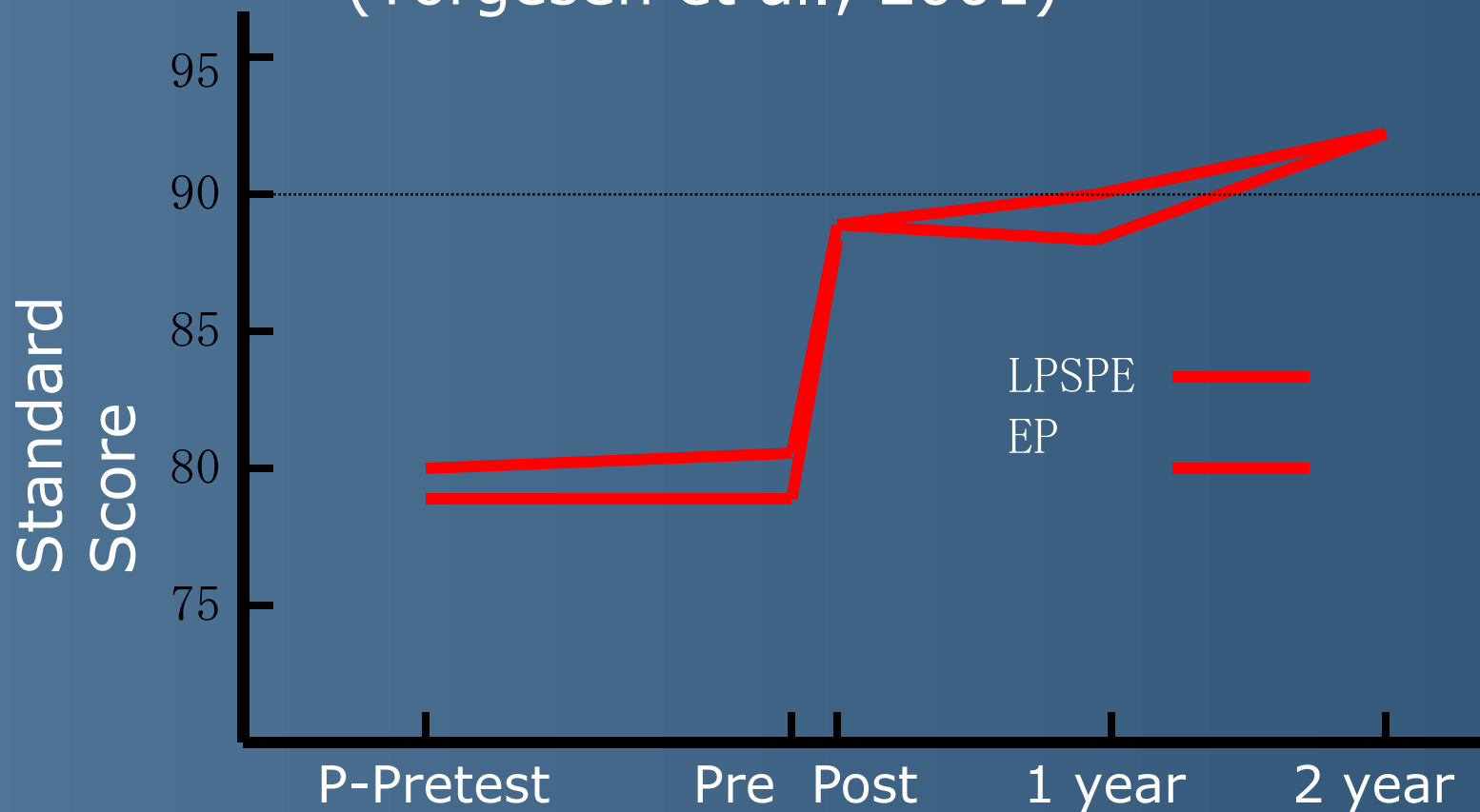
**Enhanced Classroom: 15/92 = 16%**  
**(3.2% of school population)**

**Enhanced Classroom/Small  
Group Pullout: 7/163 = 4%**  
**(<1% of school population)**

**(Woodcock Basic Reading < 30<sup>th</sup>  
percentile); fluency benchmarks add  
5 students**



## Growth in Total Reading Skill Before, During, and Following Intensive Intervention (Torgesen et al., 2001)

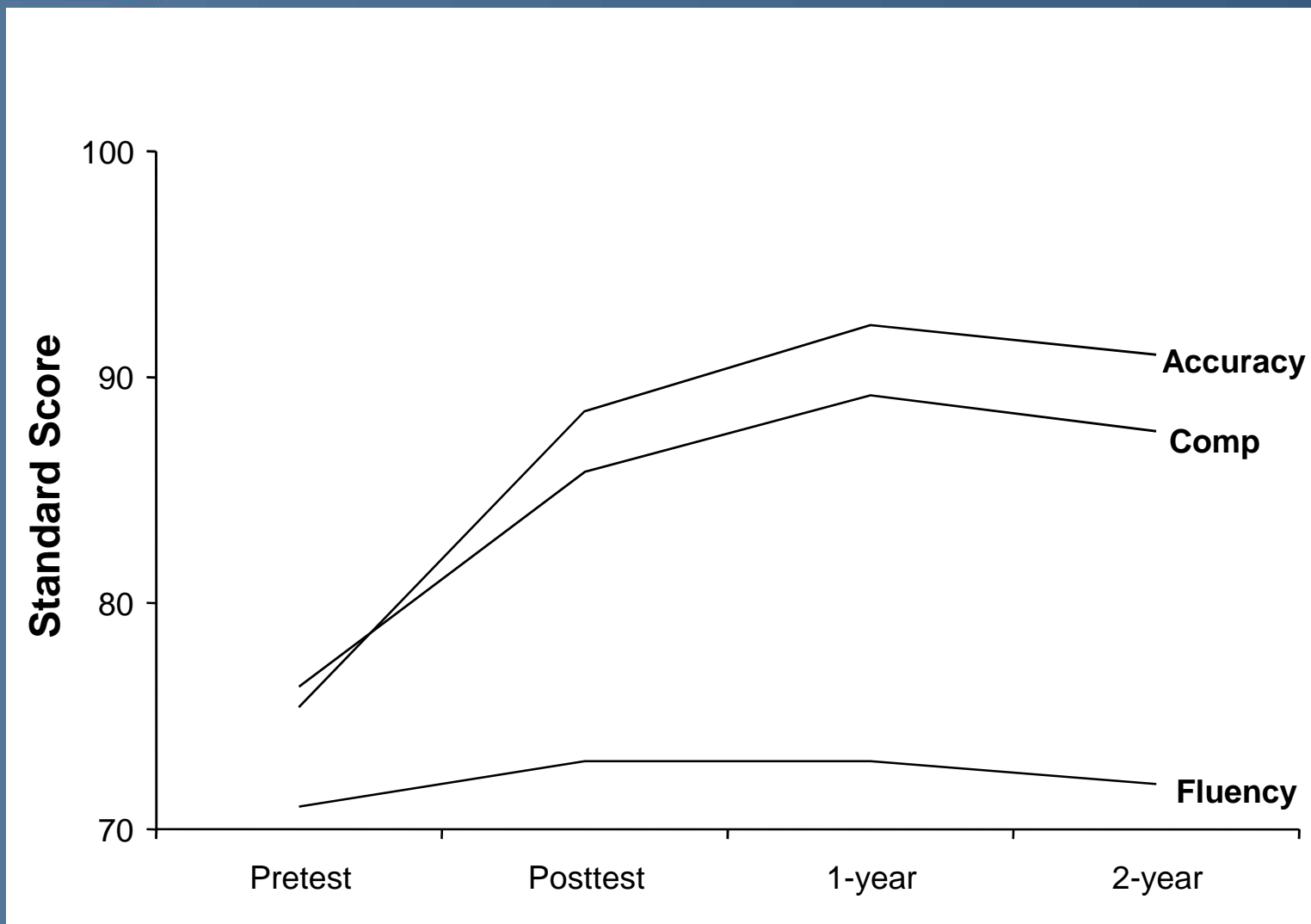


Interval in Months Between Measurements

Research Bases



## Reading fluency remained quite impaired





# Three Tier RTI Model for Academic and Behavioral Outcomes (NASDSE, 2006)

## ACADEMIC SYSTEMS

### TIER 3 *Intensive, Individual Interventions*

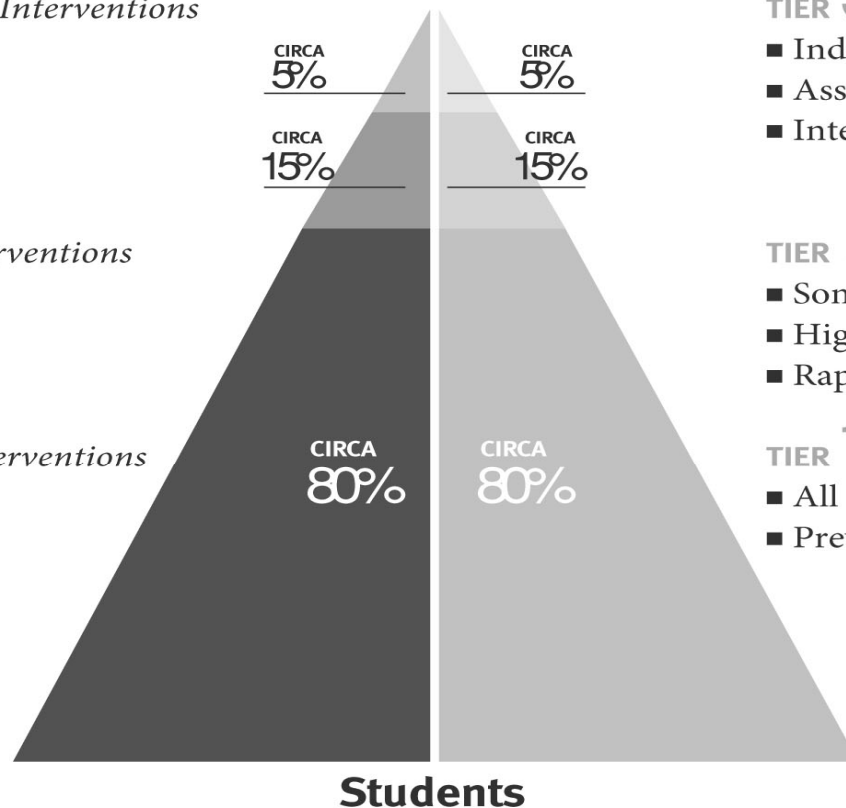
- Individual students
- Assessment-based
- High intensity
- Of longer duration

### TIER 2 *Targeted Group Interventions*

- Some students (at-risk)
- High efficiency
- Rapid response

### TIER 1 *Core Instructional Interventions*

- All students
- Preventive, proactive



## BEHAVIORAL SYSTEMS

### TIER 3 *Intensive, Individual Interventions*

- Individual students
- Assessment-based
- Intense, durable procedures

### TIER 2 *Targeted Group Interventions*

- Some students (at-risk)
- High efficiency
- Rapid response

### TIER 1 *Core Instructional Interventions*

- All settings, all students
- Preventive, proactive



# What's the Impact?

- Universal screening required in many states
- Highlights randomized trials and “scientifically” evaluated instruction
- Early intervention more common, but still a struggle
- Put the biology in LD as an active field of research and not as a metaphor or hypothesis
- Promotes interdisciplinary, **public health** approaches; LD is not just an education issue
- Research base best developed for word level disorders (most common); more to do in other reading domains and math and writing



## IDEA 2004: RTI **or** Discrepancy?

- (2)(i) The child does not make sufficient progress to meet age or State-approved grade-level standards...when using a process based on the child's response to scientific, research-based intervention; **or**
- (ii) The child exhibits a pattern of strengths and weaknesses in performance, achievement, or both, relative to age, State-approved grade-level standards, or intellectual development...
- **Children may not be identified for special education without evidence of adequate instruction in reading and math**



# Some Concluding Caveats

- Beware of accepting the null hypothesis as well as promissory notes: more research, but stick to what we know, not what we believe
- Minor signs not adequate for identification, but may be important for understanding brain function. LD **is** more than an academic skills disorder, but focus on nonresponders
- Low achievement is necessary but not sufficient, but must do research in the context of academic subtypes; build on what we know
- Structural studies must involve larger samples and need to link to functional studies
- Genetic studies need more diversity



## RTI has Great Promise, But

- What about cognitive processes and intervention in inadequate responders?
- Role of executive function- teaching self regulation part of most effective interventions
- Young children- precursors
- Adults? Is achievement enough? Adults need intervention, not just accommodations
- Accommodations- do some cognitive strengths or weaknesses facilitate adaptation?
- Intervention still must be prioritized; Move away from clinical models and embrace a public health approach





FROM "PEANUTS"

# Is Charlie Brown LD?



How can we tell if we don't evaluate his achievement levels and put him in an intervention? Major signs, not correlates



## Who is LD?

- The student who does not respond to quality instruction: **hard to teach, not unable to learn**
- Low achievement **and** inadequate instructional response, not IQ or cognitive processes
- Often preventable with early intervention
- Heritable, but neural systems are malleable
- **Advances in science occur at the boundaries of disciplines (Wilson, 1998)**



# Work Across Disciplines!

Thanks to my innumerable mentors and collaborators in neuropsychology, education, methodology, neuroscience, and genetics

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