“What’s Your Image of Dyslexia?”:

THE IMPLICATIONS OF THE NEUROBIOLOGY OF DYSLEXIA FOR PARENTS AND TEACHERS

Jeffrey L. Black, M.D.

I. NEURAL BASIS OF DEVELOPMENTAL DYSLEXIA

II. MODERN VIEW OF READING: BRAIN IMAGING

III. PROMISES AND PERILS OF PLASTICITY: UNPROVEN THERAPIES

IV. PREVALENCE, GENDER AND GENETICS

V. BRAIN DIFFERENCES AREN’T ALL BAD

Recent progress in neuroimaging and genetic research has led to an improved understanding of the etiology and brain mechanisms of developmental dyslexia. Knowledge derived from functional neuroimaging research is especially relevant for teachers when talking to families about intervention and prognosis. This information also helps parents to understand what causes their child to struggle with reading. Those affected by dyslexia can be encouraged by results that demonstrate normalization of brain function following intensive instruction and advantages in higher level thinking.

OBJECTIVES

- Discuss the brain systems for reading, the neuroimaging findings in dyslexia and how instruction changes the brain.

- List how neurobiological explanations are used to support unproven interventions for dyslexia.

- Describe the prevalence, genetics and cognitive strengths of developmental dyslexia.
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Luke Waites Center for Dyslexia and Learning Disorders
Texas Scottish Rite Hospital for Children

The Luke Waites Center for Dyslexia and Learning Disorders
Serving Children ages 5 - 14

- Founded in 1965 by Dr. Luke Waites
- Services provided:
  - Diagnostic Clinic
  - Dyslexia Laboratory
  - Research
  - Outreach
  - Teacher Training
  - Physician Training

Percy F. . . . Aged 14 . . . has always been a bright and intelligent boy, quick at games, and in no way inferior to others his age. His great difficulty has been – and is now – his inability to read.

CURRENT DEFINITION – 2003

Dyslexia is a specific learning disability that is neuro-biological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.

Aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn’t mttaer in what ordr the ltteers in a word are, the olny iprmoetnt tihng is that the frist and lsat ltteer be at the rghit pclae.  The rset can be a total mses and yoo can still raed it wouthit porbelm.  This is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the word a wlohe.

Amzanig, huh
NEURAL BASIS OF DEVELOPMENTAL DYSLEXIA: SUMMARY

The reading problems of individuals with developmental dyslexia are associated with congenital alterations in gross and microscopic structure of regions of the cerebral cortex that are involved in language.

Modeling the Reading System: Four Processors

Context Processor

Meaning Processor

Orthographic Processor

Phonological Processor

Print

Speech

An anatomical drawing of the brain showing important areas for language processing.
NON PHONOLOGICAL
LANGUAGE SKILLS

CLASSIC DYSLEXIA

NO IMPAIRMENT

PHONOLOGICAL SKILLS

CLASSIC SLI

POOR COMPREHENDERS

DYSLEXIA

NO IMPAIRMENT

SLI

left PT >> right
left PT > right
right PP >> left
right PP > left
greater asymmetry
asymmetry
more symmetric
larger cortex
average size cortex
smaller cortex


Diagram of brain activation sequence of events

NEURONAL ACTIVATION SEQUENCE

Neuronal electrical activity
↓
Energy demands
↓
Substrate utilization (glucose, ATP, PCR, O2)

Blood flow increases

Metabolic by-products (lactate*, creatine)

*Brain activation contrast mechanism: intracellular lactate production during metabolic energy demand
**Brain Imaging Techniques for Mapping Brain Function**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Contrast Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional MRI (fMRI)</td>
<td>Blood deoxyhemoglobin levels</td>
</tr>
<tr>
<td>Positron Emission Tomography (PET) FDG/015</td>
<td>Intracellular glucose uptake/blood flow</td>
</tr>
<tr>
<td>Electroencephalography (EEG) Magnetoencephalography (MEG)</td>
<td>Electrical/magnetic signal during neuronal firing</td>
</tr>
<tr>
<td>Functional MR spectroscopy (fMRSI) – lactate</td>
<td>Lactate production and clearance during glycolysis/neuronal activation</td>
</tr>
</tbody>
</table>

**Brain Imaging Techniques for Mapping Brain Function**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Contrast Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion Tensor Imaging</td>
<td>Direction of fiber tracts according to water diffusion patterns</td>
</tr>
</tbody>
</table>
**TASKS AND SUBTRACTIONS**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Stimuli</th>
<th>Processes engaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>/ / \ / /</td>
<td>Visuospatial</td>
</tr>
<tr>
<td>Case</td>
<td>BtBT</td>
<td>Visuospatial + Orthographic</td>
</tr>
<tr>
<td>Rhyme</td>
<td>LETE</td>
<td>Visuospatial + Orthographic + JEAT Phonological</td>
</tr>
<tr>
<td>Category</td>
<td>CORN</td>
<td>Visuospatial + Orthographic + Phonological + Semantic</td>
</tr>
<tr>
<td></td>
<td>RICE</td>
<td></td>
</tr>
</tbody>
</table>
Neurophysiology research has revealed that mature reading is performed by a left-hemisphere network of frontal, temporoparietal and occipitotemporal cortical regions responsible for mapping visual (orthographic) information onto auditory (phonological) and conceptual (semantic) representations.
### Pre-reading (preschool age)

<table>
<thead>
<tr>
<th>Skills to be learned</th>
<th>Deficits associated with reading disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition of letter names, some words (e.g. own name)</td>
<td>Limited knowledge of letter names, trouble rhyming words, confusion with words that sound alike</td>
</tr>
<tr>
<td>Beginning phonological awareness (e.g. awareness of similarities/differences between phonemes, nursery rhyme knowledge)</td>
<td>Slowness naming highly familiar visual stimuli (e.g. objects, colors, numbers)</td>
</tr>
</tbody>
</table>

### Decoding Stage  
(Starts in grades 1 and 2)

<table>
<thead>
<tr>
<th>Skills to be learned</th>
<th>Deficits associated with reading disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use letter cues to decode words</td>
<td>Sounding out words is inaccurate, as is spelling</td>
</tr>
<tr>
<td>Basic correspondences between letters or letter combinations and sounds</td>
<td>Few words recognized by &quot;sight&quot;</td>
</tr>
</tbody>
</table>
### Transitional Reader

**(Starts in grades 2 and 3)**

<table>
<thead>
<tr>
<th>Skills to be learned</th>
<th>Deficits associated with reading disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrate decoding and context cues for word identification</td>
<td>Word reading is inaccurate, slow and labored</td>
</tr>
<tr>
<td>Beginning to decode automatically (less conscious effort) so mental resources available for comprehension</td>
<td>Reading comprehension is limited but often superior to isolated decoding skills</td>
</tr>
</tbody>
</table>

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### Independent and Fluent Reading

**(after 3rd grade)**

<table>
<thead>
<tr>
<th>Skills to be learned</th>
<th>Deficits associated with reading disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral reading is quick with appropriate intonation and phrasing</td>
<td>Comprehension problems due to poor comprehension monitoring, working memory limitations, limited domain knowledge</td>
</tr>
<tr>
<td>Silent reading comprises the majority of reading activity</td>
<td>Reading is avoided</td>
</tr>
</tbody>
</table>

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![Brain diagram](image)
MODERN VIEW OF READING: BRAIN IMAGING: SUMMARY

Normally developing readers at all ages activate areas in the back of the left brain most strongly that quickly integrate visual, auditory and conceptual information. In contrast, dyslexic readers mostly activate systems on the right side and left front that are thought to be compensatory.
The biological abnormality of impaired reading is dependent on the cognitive processes that are required to decode the reader’s native language.
Dyslexia after intervention

MODERN VIEW OF READING: MODERN VIEW OF READING: 
BRAIN IMAGING: SUMMARY

Successful treatment of dyslexia uses scientifically supported instructional components (linguistic awareness, alphabetic principle, fluency, reading comprehension) to increase brain activation in circuits used by normal readers and which are ordinarily involved in language functions.

NEURAL SYSTEMS FOR COMPENSATION AND PERSISTENCE: YOUNG ADULT OUTCOME OF CHILDHOOD READING DISABILITY

fMRI of PPR, AIR and NI 18.5-22.5 year olds from CLS

Left posterior activation during real word reading:
PPR = NI > AIR

Functional connectivity: left OT with left IFG in NI, left OT with right prefrontal in PPR
NI developed left OT through phon. based word analysis
PPR rely on left OT for rote (visual) memory

Shaywitz et al. Biol Psych 2003
Neural Plasticity

- Cortical reorganization following experience
- Induced synaptogenesis
COLORED OVERLAYS OR LENSES

THEORY: Visual distortion with certain color frequencies, (scotopic sensitivity).

TREATMENT: Irlen overlays or lenses filter out light in the spectrum of sensitivity.

SHORTCOMINGS: SSS invalid, Irlen color detection scale not reliable, no improvement in reading.
ACOUSTICALLY MODIFIED SPEECH TRAINING

THEORY: A deficit in auditory temporal order processing underlies language-learning disabilities.

TREATMENT: Acoustically modified speech training with computer-based multimedia games provided for 1.5-2 hours/day for 3-6 weeks leads to improvements in spoken language (comprehension and expression) and reading skills.

PROBLEMS: Temporal order processing defects have not been found consistently in SLI or DD. Initial claims of FFW efficacy were based on two preliminary studies and non-experimental field trials. Subsequent independent investigations have shown gains in some aspects of language comprehension, production and phonemic awareness but no enhancement of reading skills.


Dyslexia and Perceptual Problems:
Hypotheses and Conclusions

1. Role of magnocellular system in reading is unknown.
2. Value of perceptual interventions is not proven.
3. Rapid visual and auditory perceptual systems may be defective (slower) in dyslexics.
4. Pathologic factors that disturb magnocellular systems may affect development of other areas of the brain.

DDAT (Dyslexia, Dyspraxia and Attention Treatment)

THEORY: A cerebellar deficit (CD) underlies problems with reading, spelling, handwriting, concentration, memory and coordination. CD results in problems with phonological processing, via articulatory weaknesses, and rapid naming, because of slow retrieval memory, which are accepted causal mechanisms for dyslexia. 60% of dyslexics have CD.

TREATMENT: Treatment begins with a 3 hour evaluation of balance, oculomotor control, academic skills and neurologic function leading to a customized computer-generated, home exercise plan. The exercises which take 10 minutes, twice daily, include the use of a balance board, throwing and catching bean bags, practice in dual tasking, stretching and coordination. Clients return for progress testing every 6 weeks culminating in a final assessment in about one year. The cerebellum is stimulated to develop neural pathways so the entire brain can process information properly.

PROBLEMS: Evidence against a primary cerebellar lesion causing dyslexia include: absence of overt cerebellar signs in dyslexia, absence of dyslexia in patients with cerebellar disease, lack of cerebellar neuropathology in dyslexia. The published evaluation study of DDAT included several normal readers, failed to adequately match the treatment and control groups, did not use valid and reliable outcome measures, lacked monitoring of treatment fidelity and external influences of reading. The control group made greater gains in decoding skills. Lenient levels of probability were used. Variable statistical analysis was applied to categorical data. Measures of variability were not reported.

PROMISES AND PERILS OF PLASTICITY: UNPROVEN THERAPIES: SUMMARY

While the cerebellum may appear to be dysfunctional in dyslexia, the primary pathology is located elsewhere in the brain. Microscopic anatomical, macroscopic anatomical and neuroimaging evidence demonstrates abnormalities in the perisylvian regions of the cerebral cortex. These regions project output and receive input from the cerebellum.

How Common is Dyslexia?

Eisenberg (1978): childhood rates of reading problems in urban U.S. = 30%

Berger, Yule, Rutter (1975): regression-based definition of unexpected reading problems found for boys (London = 14%, Isle of Wright = 6%) and for girls (London = 5%, Isle of Wright = 2%)

Shaywitz, et.al. (1990): research identified epidemiologic sample of second and third graders using 1.5 SD ability-achievement discrepancy identified 7.6% with reading disabilities.

Benton and Pearl (1978): most prevalence estimates 5% - 10%

Gender Differences in Dyslexia

Commonly cited male to female ratio = 3.5 - 4.0 to 1

DeFries (1989): sex ratio in family samples = 1.5 - 1.8 to 1

Shaywitz, et.al. (1990): 1.25 boys to 1.0 girls
SEX DIFFERENCES IN
DEVELOPMENTAL READING DISABILITY

N = 9799 (50% males) 7-15 yrs. From 4 epidem. studies in New
Zealand and United Kingdom
RD defined by single word reading at lowest 15% or 1 SD
below predicted by IQ
20% boys and 11% girls identified RD (2 males: 1 female)
Method. Strengths: large sample size, representative of general
population, not reliant on referral

JAMA, April 28, 2004

Summary of Gender and
Prevalence Studies

Five to ten percent of school-age children
have significant difficulty reading at a level
predicted by their general level of
intellectual/cognitive functioning. The
prevalence of this difficulty is greater in boys
than girls. Behavioral features associated
with male gender result in a greater number
of boys being identified as learning disabled
by their schools.

Summary of Genetic
Investigations

The phonological processing deficit that
underlies developmental dyslexia is heritable.
The mode of genetic transmission is not
established and probably diverse. Non-
genetic causes are not commonly identified.
Genotype – Environment Correlation

Genes that make it difficult to read are also likely to lead to less than normal reading practice.

The least motivated children in the middle grades might read 100,000 words per year, while the average children at this level read 1,000,000. The figure for the voracious middle grade reader might be 10,000,000 to 50,000,000.

Nagy & Anderson (1984) RRQ
<table>
<thead>
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<th>SIGNS OF HIGHER LEVEL THINKING IN DYSLEXIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick grasp of new concepts</td>
</tr>
<tr>
<td>Talent solving puzzles and building things</td>
</tr>
<tr>
<td>Good comprehension of stories, read or told to him</td>
</tr>
<tr>
<td>Ability to get the gist and think outside the box</td>
</tr>
<tr>
<td>Learns better through meaning than rote</td>
</tr>
<tr>
<td>Excellence in math, science, creative writing</td>
</tr>
</tbody>
</table>