The Evolution of the Reading Brain: Implications for Reading’s Development, Instruction, and Disorders

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We feel quite truly that our wisdom begins with that of the author...By a law which perhaps signifies that we can receive the truth from nobody, that which is the end of their wisdom appears to us as but the beginning of ours.

-Marcel Proust
Metaphor for Evolutionary-Biological Dimension in Reading: Squid

• Early neuroscientists used the long central neuron of the squid to study how neurons work.

• Today’s cognitive neuroscientists use reading to study how the brain works when confronted with new learning.
Principles of Brain Design Underpinning Cultural Inventions

- Ability to form new **connections**
- Capacity for “working groups” of neurons to **specialize** (e.g., pattern recognition)
- Capacity for **automatization**
Novel Connections among Older Structures

Existing circuits of neurons -

- originally designed for vision, language, and cognition ---

learned to forge whole new connections and pathways.
Dehaene’s Concept of “Neuronal Recycling” for Numeracy and Literacy
Neuronal Niche
Sumerian Pedagogy

Emphases on phonology, orthography, semantics, syntax, and morphology

and caning!
Greek Writing and the Alphabetic Principle

The insight that words are made up of sounds and each sound can be signified by a symbol.
Brain can rearrange itself in multiple ways to read.

Bulger, Perfetti, & Schneider
Development of Insights into Written Language by the Species

It took the species 2000 years of insights from first logographic scripts to first alphabet:

• Symbolic representation
• System of symbols for language and concepts
• System of symbols for each sound
Development of Reading

The child is given 2000 days to gain the same insights.
Implications of Evolutionary View for Reading Development

• No Genes specific to reading
• No “Reading Center” in brain, therefore:
• Each new reader must create a new reading circuit from older structures & their connections
“Children are wired for sound, but print is an optional accessory that must be painstakingly bolted on.”

- Steven Pinker
fMRI

- The f represents **functional** uses of MRI
- Measures changes in blood flow to the brain over time as a function is performed
- Creates a map of activation overlaid on brain anatomy
How do we get kids to do this?

- Mock scanner, friendly researchers, lots of practice
Moriaty

You have let me have more fun in 3 days than I could have in any other place.

Just think of it! I'm playing a game when at the same time I'm a research ginny pig.

And who knows I might help someone else my age.

If they have any brain problems, while still earning money.

And what do you think beats that? Nothing.

Thanks.
Cognitive Development: Concepts Matter

Concepts in first language are essential platform for concepts and vocabulary in second language.
Reading never just happens.

Everything matters:

• Visual and auditory development
• Cognitive development
• Language development
• Social development
• Emotional development
Everything Matters

Phonemes (smallest sounds)

Orthographic Parts: Letters
  Letter patterns
  Common Words

Semantic Meanings of Words

Syntactic Uses of Words

Morphemes
Phonemes Matter

- Phoneme Awareness
- Explicit emphases on decoding
Orthography Matters

- Letters
- Letter Patterns
- Conventions of Print

Left to right scanning
Sticker Story: Horses

I like horses. Horses have other horse friends. Horses like carrots. You wouldn't think they could, but they can put their legs straight up. Horses make you feel good. My dad wants a horse, but my mom says no. When I am 16 or 20 I will buy my own horse.
Semantics Matters

- Vocabulary development
- Semantic breadth and depth
- Polysemy (multiple meanings) and Semantic Flexibility
Semantic Development: Words Matter
32 million word gap
• By age four years: an average child in a professional family would have accumulated experience with almost **45 million words**

• an average child in a working-class family would have accumulated experience with **26 million words**

• an average child in a welfare family would have accumulated experience with **13 million words**

- Hart & Risley, 2003
• Academic Achievement:
Advanced children (75th percentile) are about a "year" ahead of average children, while delayed children (25th percentile) are about a “year” behind. (Bankson, 1977; Dunn & Dunn, 1982)

• Quality of Communication:
With talkative parents by the age of four, the children had heard about 750,000 times that they were right, and about 120,000 times that they were wrong. And with very taciturn parents, it was almost the reverse, they only heard they were right about 120,000, and they had heard they were wrong about 250,000 times. (Hart & Risley, 1995)
Multiple Meanings

- Common in the English Language; 50% of English Words have more than one meaning
- Knowing a single word creates a connection to many other words
Word Poverty

• “…economically and educationally disadvantaged children may have one-half the oral language vocabulary that is typical of children from middle-class homes with educated parents (Biemiller, 1999; Hart & Risley, 1995)

• By the intermediate grades, we found that the majority of the lower SES children in our study sample were poorly prepared for the demands of academic, expository writing (Moats, Foorman, & Taylor, 2006).
“The only thing Harry liked about his own appearance was a very thin scar on his forehead that was shaped like a bolt of lightning.”

- J.K. Rowling
Morphemes Matter

• Orthographic, semantic, and syntactic information

jam jams jamming unjammed
Periventricular nodular heterotopia
“Leaving morphological analysis to be discovered by students on their own means that those who are not inherently linguistically savvy are likely to be left behind their peers in the development of vocabulary, word reading and comprehension, and spelling.”

(Carlisle, 2003)
The more you know about a word ...the faster you will read and comprehend that word.

- Phonological processes
- Orthographic processes
- Syntactic processes
- Morphological processes
- Semantic processes
Timeline of Expert Reading

- **Visual Feature Analysis**
- **Executive and Attention Processes**
- **Motor Plan**
- **Saccade Begins**
- **Semantic and Comprehension Processes**

- **Visual Areas**
- **Visual Word Form Area (BA37)**
- **Semantic and Phonological Processes**
At the heart of reading, 100 milliseconds allow us "time to think new thoughts".
Implications of Evolutionary View for Sources of Reading Failure

Weaknesses in:

- Older structures
- Circuit connections
- Efficiency in specialized groups and/or in circuit connectedness
- Different circuit altogether
Normal Readers

Dyslexic Readers

Visual Recognition
0-100 MSEC

Word Specific Activation
150 MSEC

Phonological Processing
180-300 MSEC

Semantic Processing
200-500 MSEC

Delay

Delay

Delay

Delay
Most Overlooked Aspect in Dyslexia Diagnosis and Intervention

Failure to achieve **automaticity & fluency**
Rapid Automatized Naming (R.A.N.)
What does it mean to be a fluent reader?

• “In fact, the automaticity with which skillful readers recognize words is the key to the whole system…The reader’s attention can be focused on the meaning and message of a text only to the extent that it’s free from fussing with the words and letters.” (Marilyn Adams)
61% AA
54% H
26% EA
• If unresolved, reading acquisition failure will limit the future potential of 10 million American youth.

NRP report, 2000
Effects of Poor Reading Fluency

- Lowers student achievement
- Lowers student’s ability to keep up with classroom expectations
- Lowers self-esteem
- Lowers student’s interest in independent reading
- Lowers student’s interest in learning
Fluency

- Is not a matter of speed
- It’s about being able to utilize all the knowledge about a word fast enough to have time to think and comprehend
- Fluency does not ensure comprehension
- Gives the executive system enough time to direct attention where it’s needed
  - Infer, understand, predict
At a meta-level, fluency intervention must address the rapid activation and retrieval of the five interconnected systems if fluent comprehension is to be attained.
Fluent, Feeling Brain

• A fluent, comprehending reader “feels” more than ever before

• Growing activation in the limbic system

• Affective network determines what patterns and strategies are important to the individual
  • Helps us prioritize and give meaning to what we read
How much reading changes us depends on what we read and how we read it

Multiple readings of same work can have different reactions

Predict, infer, plan, leverage background knowledge

The relationship between text and life is dynamic

“We bring our life experiences to the text, and the text changes our experience of life”
RAN as a Predictor

- Kindergarten (Kirby 2001, Sunsesth & Bowers, 2002)
- Letters & Numbers predict reading fluency (Kirby)
- RAN/RAS correlates with:
  - Spelling
  - Reading fluency
  - Comprehension
  - Reading accuracy of unfamiliar words
- Math Fluency
Distribution

- Double Deficit: 53%
- Naming Speed Deficit: 21%
- Phonological Deficit: 17%
- Other Reading Impaired: 10%
The Expert Reading Brain
Part 2: The Implications of a New Conceptualization of the Evolving Reading Brain and Dyslexia for Intervention
Implications of Evolutionary View For Reading Intervention

Intervention must address:

- Development of each recruited structure
- System Connections
- Automaticity
- Time to comprehend and think new thoughts
Principles of Intervention

- Equal weight in instruction on accuracy and speed;
- Explicit instruction in all components of linguistic knowledge: that is, emphasis in instruction on phonology, orthography, semantics, syntax and morphology;
- Explicit emphasis on comprehension strategies.
Principles Underlying Developmental, Component-based Fluency Intervention

1. Explicit teaching in each component area.
2. Explicit teaching of component connections (e.g., between phonology and orthography, semantic and retrieval-processes, morphology and syntax).
3. Systematic attention to move from accuracy to rapid rates in each process.
4. Systematic attention to sublexical, lexical, and connected text levels.
5. Integration of component parts in comprehension.
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Program Components

- **PHAB/DI** - Phonological Analysis and Blending/Direct Instruction
- **PHAST** - Phonological and Strategy Training
- **RAVE-O** - Retrieval, Accuracy, Vocabulary, Engagement, Orthography
- **CSS** - Classroom Survival Skill
- **MATH** - Math/Direct Instruction

**ALL GIVEN IN 70 1 HOUR SESSIONS by Project Supplied Research Teachers**
A direct instruction program using parts of: READING MASTERY, FAST CYCLE I/II PROGRAM CORRECTIVE READING PROGRAM (Englemann & Bruner, 1988; Englemann, Johnson, Carnine, et al., 1988)
PHAST:

• An Integrated Phonological & Strategy Training Program
• Now Called EMPOWER READING
The RAVE-O Model

The More A Student Knows About a Word, the Faster the Word can be Decoded and Comprehended

APPLICATION!
Read for fluency
Read for meaning
Read to think new thoughts
Who is RAVE-O for?

• RAVE-O is designed for first through fourth graders;
• Tier II or III program for students reading appx. one year behind their peers;
• Common measure: One SD below norm on Word Identification, Nonword Reading, and Reading Fluency on WJIII
RAVE-O and RTI

Layers of intervention responding to student needs

- Each tier provides more intensive and supportive intervention
- Aimed at preventing reading disabilities

- Dr. Joseph Torgeson, 2004
RAVE-O Tier II and Tier III

Tier I
Whole Class Instruction

Universal Screening: Determine students with decoding deficits

Tier II (Intervention)

RAVE-O
Five Days per Week or Three Days per Week

Progress Monitoring

Tier III

If lack of progress - complete a more diagnostic assessment
Problem solving model: determine program plan
Special education referral? Other?
How can RAVE-O help?

• RAVE-O successfully increases rate and accuracy of word retrieval.

• RAVE-O successfully increases rate and accuracy of word-level and text reading and comprehension.

• RAVE-O expands vocabulary breadth and depth

• Provides a foundation for learning principles of English syntax and morphology.
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What **RAVE-O** is NOT?
Big Picture

• Study of English letter patterns and morphology
• Word segmentation skills
• Strategies for semantic skills and vocabulary growth
• Automatization of word identification skills
• Text comprehension and fluency
Key Advantages

• Systematicity
• Connectivity
• Engagement
Systematicity

- Multi-componential: addresses all underlying systems related to reading (not just a single component)
- Each component builds on the others within a lesson and within a unit and within the entire program
- Focus shifts from accuracy to automaticity
RAVE-O Characters: Metacognitive Strategies Embodying POSSuM
Phonology Emphases: Words are Connected by Sound

How do I analyze what I know about words?
Word Segmentation Skills

jam

jam

jam

jam

jam
Strategies for semantic skills

- Many Interesting Meanings
- Many Interesting Connections
English Morphology

Meaning
• Each ‘Ender Bender’ bends the meaning of a word
  • ‘s’: plural or 3ps
  • ‘ing’: happening right now
  • ‘er’: more, person, or whole new meaning

Orthography
• Each ‘Ender Bender’ bends the end of a word
  • ‘s’: Look at that ‘s’ car go!
  • ‘ing’: Double Trouble
  • ‘er’: Double Trouble
Ender Benders
Syntax, Minute Stories, and DEEP READING

- Increases fluency with connected text
- Facilitates semantic and syntactic flexibility: e.g., Sam tracked the tracks by the tracks.
- Illustrates the polysemous nature of words, syntactic functions, morphemes
- Gives students (and teachers) opportunity to appreciate own novel thought through Think THRICE strategies
- It’s a “Chapter Book”!
Think Thrice
You are a thoughtful reader when you…

Think Ahead!
Think Back!
Think for Yourself!
MINUTE STORIES

- Increases fluency with connected text
- Facilitates semantic and syntactic flexibility: e.g., Sam tracked the tracks by the tracks.
- Illustrates the polysemous nature of words
- Gives students (and teachers) opportunity to see the change in reading rate
- It’s a “Chapter Book”!
Results of RAVE-O Interventions

• Second and third graders (7-9 years old)

• Three types of intervention

• School-day pull-out (NICHD; Atlanta, Boston, and Toronto; ten years)

• Summer School (RFBD; 4 hours/day, 4 weeks)

• After-School (IES; Phoenix & Boston; 1 hour/day, 3 days/week)
Program Results

- All interventions performed better than control
- Multi-dimensional programs performed better than phonological programs alone.
GORT ORAL READING QUOTIENT Regression Analysis by TREATMENT GROUP

Time (in days) Since Study Onset

- MATH+CSS
- PHAB/DI+CSS
- PHAB/DI+RAVEO
- PHAB/DI+WIST
RAVE-O Multiple Definitions Test
A New Set Towards Words

# Words - 2 or more Definitions

- 0 Sessions
- 70 Sessions

MATH-CSS  PHAB-CSS  PHAB-RAVEO
Audio Task
- Task vs. Rest
- Rhyme vs. Match

Visual Task
- Task vs. Rest
- Rhyme vs. Match

- $p < .005$
- $k > 5$
“A good story ends with an open door…”

-John Updike
What are the deeper implications of an evolving reading brain for the children of a digital culture?
Reading Brain is *tabula rasa.*

no single circuitry reflects the demands of language and medium
Digital Reading Brain emphasizes:

- massive information processing and production
- speed and efficiency
- multi-tasking and interactive communication
Socrates feared that print would give the illusion of truth and create no ambition in the young beyond the superfluity of knowledge.
Characteristics of on-line reading in the young reading brain

• Continuous partial attention
• Distractibility
• Demand for immediate information
• Efficient multi-tasking and integration across diverse sets of information
On-line Information

- Immediacy
- Voluminousness
- Prioritized often by popularity of hits rather than adjudicated sources of knowledge
“A culture can be judged by how it pursues three lives: the life of activity and productivity, the life of enjoyment, the life of contemplation.”

Aristotle
“Digital Reading”
Brain: Life of Activity
Life of Enjoyment
Cognitive Effects: Brain Imaging Studies

“Even if we can learn while distracted, it changes **how** you learn, making the learning less efficient and useful”

“Multitasking hinders learning”
Russ Poldrack (2006)
Proceedings from National Academy of Science
The scariest thing about Stanley Kubrick’s vision wasn’t that computers started to act like people but that people had started to act like computers. We’re beginning to process information as if we’re nodes; it’s all about the speed of locating and reading data. We’re transferring out intelligence into the machine, and the machine is transferring its way of thinking into us.

Nick Carr in “Do you trust Google?”, WIRED, Jan. 2008
Cognitive Effects: Task Switching Effects

- Increases amount of time needed to learn
- Changes learning style qualitatively by use of less flexible memory system
- Loss of attention and time used to switch tasks adversely affects ability to learn more complex facts and concepts.

- Gasser & Palfrey, 2009
Social Effects

Seokyong Lee for The New York Times
“It would be a shame if brilliant technology were to end up threatening the kind of intellect that produced it.”
“Deep Reading” Brain

• Slower, deep reading processes.
  • Inference
  • Analogical Thinking
  • Critical Analysis and Deliberation
  • Insight and Epiphany
  • Contemplation

• The Underpinnings of Wisdom and Virtue
Evolving Conclusions

We are both what we read and how we read
For more information on RAVE-O:

- Contact Dennis Hallinan at dennis.hallinan@tufts.edu
- Visit our website: ase.tufts.edu/crlr