The Brain and Reading Development: From Infancy To Adolescence

Dennis L. Molfese, Ph.D.
Victoria J. Molfese, Ph.D.
University of Louisville

(logo of ECRC)

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ECRC
Early Childhood
Research Center

Developmental Neuroscience Laboratory

Collaborators:
E. Todd Brown, Ph.D.
Roskoe Dykman, Ph.D.
David Gozal, M.D.
Kyle Harvison, Ph.D.
Linda Mayes, M.D.
Kathleen Rudasill, Ph.D.
Arlene Tan, Ph.D.
Paul Yoder, Ph.D.

Postdoctoral Fellows:
Spencer Kelly, Ph.D.
Matthew Kelly, Ph.D.
S. Fonaryova Key, Ph.D.
Guy Dove, Ph.D.

Sabbatical Fellows:
Teri Bonebright, Ph.D.
Jeannie Johnson, Ph.D.
Mary June Mosely, Ph.D.
Harry Whitaker, Ph.D.

Researchers
Natalie Armstrong, B.S.
Jennifer Beswick, M.A.
Krista Girrod, B.S.
Brittney Haines, B.S.
Danielle Henderson, B.S.
Christy Osborne, B.A.
Adrienne Roman, B.A.
Alysia Rue, B.A.
Mathew Stone, B.A.
Lauren Tucker, M.A.
Rachel Waford, M.A.
Jamie White, B.A.

Students (current)
Maria Barnes, M.A.
Eric Brian, M.A.
Melissa Ferguson, M.A.
Lindsay Huffman, B.S.
Jill Jacobi-Vessels, M.A.
Andrew Molnar, B.S.
Nikki Pratt, Ph.D.
Christopher Warren, M.A.
Jia Wu, M.A.

National Institutes of Health Reading and Learning Disabilities Network

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Topics

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Brain Myths
Brian Development
Brain Organization for Language and reading
Concurrent Study of Reading Skills
Impact of Brian Organization on Acquiring Other Skills
Brain Model For Concept and Skill Acquisition

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Brain Research is popular!

Brain Research Is Popular!

- Researchers, teachers and parents are looking for evidence of "what works" in helping children to be successful in school
  - Brain Research a popular basis for justifying instructional approaches & educational technologies
  - Touting "brain research" sells new curricula and books
  - Many of the popular beliefs about "brain functions" are not correct, incomplete, or simply wrong.

Medical Myths Even Physicians Believe
ScienceDaily (Dec. 21, 2007)

- **Medical Myths Even Physicians Believe**
  ScienceDaily (Dec.21, 2007)
  www.sciencedaily.com/releases/2007/12/071220195639.htm

- People only use 10 percent of their brains
- Hair and fingernails continue to grow after we die
- Eating turkey makes you sleepy
- People should drink at least eight glasses of water a day
- Shaving hair cause it to grow back faster or coarser
- Reading in dim light ruins your eyesight

These are myths - there is no definitive research support:
People make things up

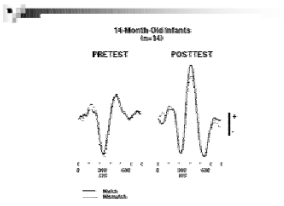
Brain Myths:

Brain Myths:

- **You Only Use 10% of Your Brain**
  www.csicop.org/si/9903/ten-percent-myth.html
- Resulted in 42,600,000+ sites for "you only use 10% of your brain".
- Very popular topic
- But research does not support this view....

Brain Myths: The Learning Process Takes a Long Time
(Picture of a graph labeled pretest and Posttest with two wavy lines. One with a steeper curve cord to the other.)

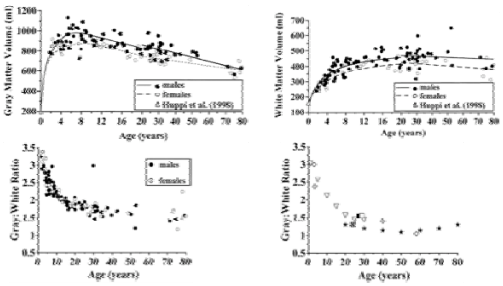
Brain Myths:
The Learning Process Takes A Long Time



Molfese, Morse & Peters, 1990

10 min./day for 5 days.

"All Brain Development is Over By 5 Years of Age"



Courchesne et al. (2000)

How To be a Brian Myth Buster!!!

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- Ask Whose research is being referenced.
- Ask where the research is published (science/ education journals)?
- Ask for details, not just generalization
- Make Google one source of information for gathering facts.

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Dynamic Brain Development

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Brain components develop at different rates, different times at every level of nervous system.

a. Brain anatomy
b. Cortical layers
c. Gray (Neuron) & White (Fiber Tracts) Matter
d. Functional interactions change
e. Synaptic density
f. Impact of Developing neurons

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- Cortical layers.
- Gray (Neuron) & White (Fiber Tracts) Matter.
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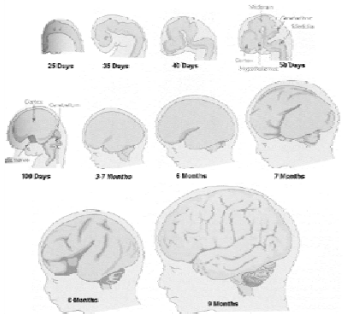
- Impact of Developing neurons.

Gross Brain Anatomy Changes During Development

Gross Brain Anatomy Change During Development (Pictures of babies brains in the development stages from 25 days to 9 months.)



Neuron Structure & Density Change With Age

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Conel, 1985

From Conception Different Brain Regions Grow at Different Rates

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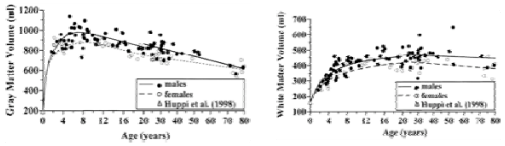
Gilmore et al., 2007

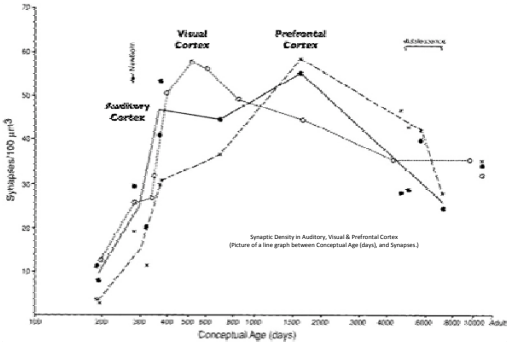
Growth Rates of Neurons (Gray) & Nerve Tracts (White) Change Across The Lifespan



Growth Rates of Neurons (Gray) and Nerve Tracts (white) Change Across The Lifespan
(Picture of two graphs representing males and females on a line graph.)

Courchesne et al. (2000)

Synaptic Density in Auditory, Visual & Prefrontal Cortex

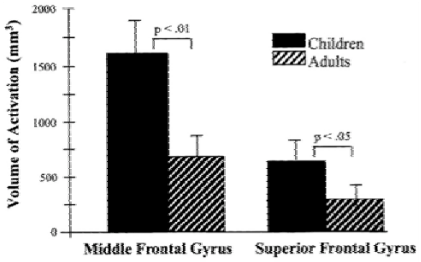


Synaptic Density in Auditory, Visual & Prefrontal Cortex
(Picture of a line graph between Conceptual Age (days), and Synapses.)

Huttenlocher & Dabholkar, 1997

Children Use More Brain Area For Processing Than Adults

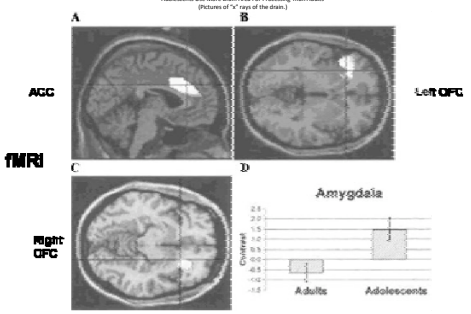
Children Use more Brain Area For Processing Than Adults
(Picture of a bar graph showing the difference between Volume of activation, Middle Frontal Gyrus, and Superior Frontal Gyrus.)



Casey et al., 2000

Adolescents Use More Brain Area For Processing Than Adults

Adolescents Use More Brain Area For Processing Than Adults
(Pictures of "x" rays of the brain.)



(A–D) Activation in pre-ACC, left OFC, right OFC, and amygdala.

(Blakemore & Choudhury, 2006, p. 307)

Summary - Brain Development

Summary-Brain Development

Brain Components develop at different rates, different times at every level throughout the lifespan.

- Anatomical brain changes occur at different rates, times.
- Cortical layers.
- Gray Matter & White Matter.
- Interactions between different layers, structures & region.
- Developing neurons impact neural functioning.

Brain components develop at different rates, different times at every level throughout the lifespan.

a. Anatomical brain changes occur at different rates, times
b. Cortical layers
c. Gray Matter & White Matter
d. Interactions between different layers, structures & regions
e. Synaptic density differs by layer & region
f. Developing neurons impact neural functioning

Overall Brain-Behavior Development Model

Divergence - Convergence - Emergence

DIVERGENCE - Brain development proceeds at different rates across the brain at different times

CONVERGENCE - At different points in time increasing integration between neural areas and cognitive dimensions they support occurs

EMERGENCE - new levels of integration, increases in processing speed, reductions in neurocognitive effort, increasing plasticity

Static and Dynamic Views of Cognitive Skills

Static and Dynamic Views of Cognitive Skills

- Static views are prevalent
  - diagnostic labels – "dyslexia" or "struggling" readers
  - brain sites (left brain, prefrontal lobe, "10% of your brain")
  - domains, such as language skills, reading skills
- Dynamic views should be more prevalent
  - Diagnostic labels are expected to change with intervention (dyslexia, ADHD, autism): this is the expectation
  - Intervention should lead to changes in brain function and functional "efficiency"

Questions To Ask: Why Are There Persistent Reading Differences?

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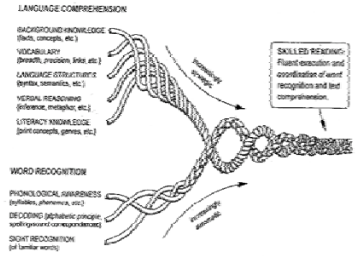
Summary from Joseph Torgesen

- Struggling readers miss opportunities to learn to recognize individual words and words in context -- they read inaccurately and they don't read very much.
- By 3-4 grade, their "sight word vocabulary" is severely restricted compared to good readers the same age
- After they become more accurate readers, there is a huge gap in the number of words they can recognize by sight.
- They can't catch up because good readers are continuing to add words to their sight vocabulary at a fast rate.

Maximizing Skilled Reading - Many Skills Are Involved

Maximizing Skilled Reading Many Skills Are Involved.
(Picture of a diagram representing Skilled Reading.)

The Many Strands that are Woven into Skilled Reading
(Scarborough, 2001)



Questions To Ask: What Matters Most In Understanding How Reading Begins?

- What we know about reading from research
  - Practice is important
  - Good reading requires
    - accurate perception of phonemes (speech sounds).
    - linking phonemes to letter symbols (encode), and recognize those letter symbols as phonemes (decode).
    - Oral Language Skills - vocabulary, language knowledge, reasoning.

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Dynamic System View

"Dynamic System View"

- Change in speech perception skills and phonological processing skills in beginning readers (or younger) impact the development of language and reading skills.
- Information processing during reading is reflected in brain processing
- Differences in reading skills is reflected in brain processing.

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- Information processing during reading is reflected in brain processing
- Differences in reading skills is reflected in brain processing

What Do We "Know For Sure" About Early Brain Activity& Later Language?

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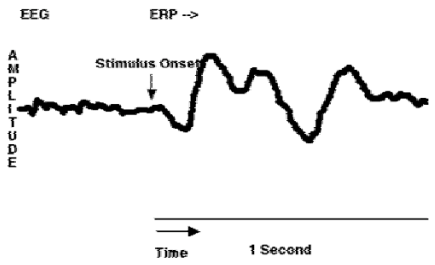
???

Event Related Potential –ERP
(Picture of a line graph labeled amplitude vs. time.)

Event-Related Potential - ERP



Event-Related Potential – ERP

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- Rapid Temporal Information (ms)
- Developmentally Sensitive
- Correlates with Cognitive Abilities
- Predictor of Later Development

Rapid Temporal Information (ms)
Developmentally Sensitive
Correlates with Cognitive Abilities
Predictor of Later Development

Long Known That Brain Responses of Reading Impaired Children Differ From Normal Readers

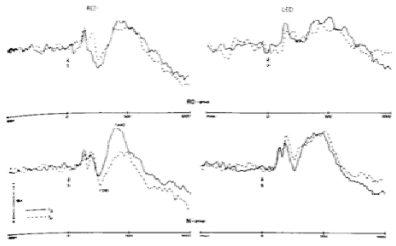
Long Known that Brain Responses of Reading Impaired Children Differ from Normal Readers 8 – 12 year olds reading 4 letter words (Picture of two graphs labeled Reading Impaired vs. right ear dominate and left ear dominant.) (Picture of two graphs labeled Control vs. Right ear dominant and left ear dominant.)

8- and 12-Year Olds Reading 4-Letter Words

Right Ear Dominant **Left Ear Dominant**

Reading Impaired

Controls



Blaxter et al, 1980

Findings from Longitudinal Studies

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- Infants were recruited at birth
- Children were tested yearly on their birthdays- or within 2 weeks- on behavioral assessments of cognitive skills and ERP measures of speech perception.
- Parents provided information on home activities, child health, and demographics.

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Longitudinal Studies of Early Predictors of Language and reading skills.

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- Underlying Hypothesis: good language ad reading skills required:
- Accurate perception of Phonemes (speech sounds)
- Linking phonemes to letter symbols (encode)
- Recognize letter symbols as phonemes (Decoding Faster Processing.)

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Accurate perception of phonemes (speech sounds)

Linking phonemes to letter symbols (encode)

Recognize letter symbols as phonemes (decode)

Faster Processing

The Question is

How early do such difference occur in development and can we do anything to bring about change?

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Methods

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Infants < 36 hours, re-tested yearly
CV syllables: (set 1) bi, di, gi, bae, dea, gae, bu, du, gu, (set 2) bae, gau + 2 NSP controls
Duration= 50 ms + 250ms Intensity= 80 dB SPL (A), Free field, Varied ISI (3- 8 sec.) Blocked random order (25 repetitions)
Procedures: Electrodes referred to linked ears (A1, A2), Matched impedances < 5 k Ohms, IEI < 1 k Ohm

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  bae dae gae
  bu du gu
  (Set 2) bae gae + 2 NSP controls

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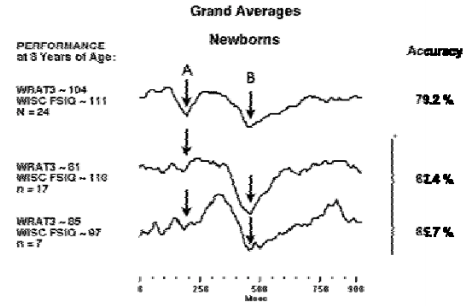
Molfese & Molfese, 1985

Newborn Responses to Speech Predict Later Reading Skills

Newborn Responses to speech predict later reading skills. Newborn infants at risk require ~200 ms longer to process/ discriminate speech sounds

NEWBORN Infants at risk require ~200 ms longer to process/discriminate speech sounds

(Picture of three line graphs showing Newborns vs. the performance at 8 years of age, and the accuracy.)

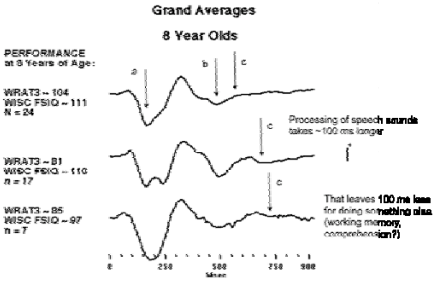


Molfese, 2000

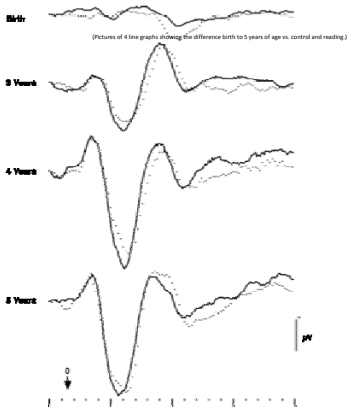
8 Year olds' responses to speech and later Reading skills.

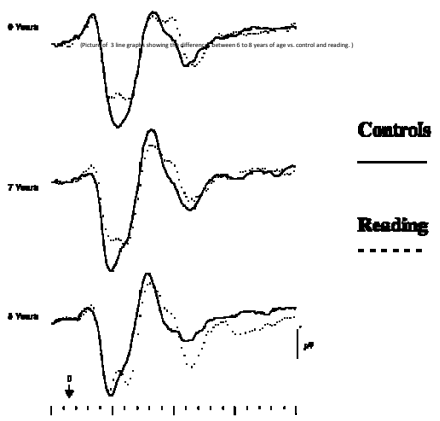
8-Year Olds' Responses to Speech & Later Reading Skills

- (Picture of three different line graphs showing the performance at 8 years of age.)



(Pictures of 4 line graphs showing the difference birth to 5 years of age vs. control and reading.)

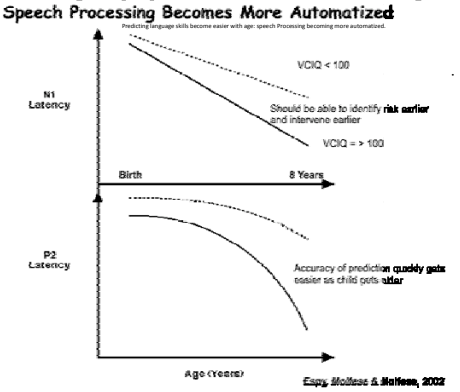




(Picture of 3 line graphs showing the difference between 6 to 8 years of age vs. control and reading.)

Predicting Language Skills Become Easier With Age: Speech Processing Becomes More Automatized

Predicting language skills become easier with age: speech Processing becoming more automatized.



(two line graphs showing the difference between birth to 8 years, and N1 Latency represented in a straight downward pointing line. The second graph shows the difference between P2 Latency between age represented in a arched line pointing downwards.)

Espy, Molfese & Molfese, 2002

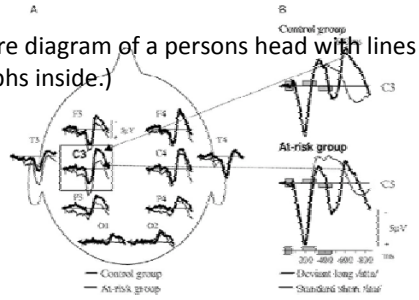
Finding from other Laboratories Also Show Links between Early Brain Reponses to Speech and later language Skills

Findings From Other Laboratories Also Show Links Between Early Brain Responses to Speech and Later Language Skills

6-month Olds Differing in Familial Risk Respond to Speech Syllables

6 Month olds differing in Familial Risk Respond to speech syllables.

(Picture diagram of a persons head with lines graphs inside.)



Lyytinen et al, 2005

Familial Risk & 5 Year Olds

Children with familial risk of dyslexia were identified using parental responses to a multiple-choice Parental Learning History Questionnaire

N = 20, 14 males, Mean age = 61.6 months (SD=7.39)

10 Risk Children's parents indicated history of reading & writing difficulties

ERPs recorded to speech syllables

Molfese et al. 2008

Familial Risk & 5 Year Olds

Regression analyses indicated strong relationship between the ERP responses to speech and familial risk

Regression analyses indicated strong relationship between the ERP responses to speech and familial risk.

(Table labeled model summary.)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.[illegible]a	.[illegible]	.[illegible]	[illegible]	.[illegible]	[illegible]	[illegible]	[illegible]	.[illegible]
2	.770b	.628	.563	2.27803	.338	14.846	2	17	.000
3	.907c	.823	.786	1.57805	.195	16.165	3	14	.000
4	.924d	.872	.829	1.37042	.050	5.940	2	12	.038

a. Predictors: (Constant), FRDV2

b. Predictors: (Constant), FRDV2, FLCA3

c. Predictors: (Constant), FRDV2, FLCA3, FRDV3

d. Predictors: (Constant), FRDV2, FLCA3, FRDV3, FRCA2

Molfese et al. 2008

ERPs to /ga/

ERP to/ga/

(Picture of two line graphs labeled LH and RH)

LH

RH

Molfese et al. 2008

Take Away Message

Take Away Message

- Brain responses at birth differ between normal developing children and children at risk for later reading an language problems
- Such differences persist into adolescence

Brain responses at birth differ between normal developing children and children at risk for later reading and language problems

Such differences persist into adolescence

Concurrent Study of reading Skills:
Evidence of Processing Differences

Concurrent Study of Reading Skills: Evidence of Processing Differences

- School District contract.
- New reading program was planned.
- Children and families with different reading skills wanted to understand how reading skills could be impacted by the new program.

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- New reading program was planned
- Children and families with different reading skills wanted to understand how reading skills could be impacted by the new program

Children Participating N= 27

Children Participating N = 27

School Identified Reading Groups	Males	Females
Above (2 years +)	4	4
Average	4	5
Below (2 years -)	5	5

Ages: 9 yrs. 3 mo. - 12 yrs. 1 mo.

School Identified reading groups, above (2 years +) 4 males, and 4 females, Average 4 males, and 5 females, and Below (2 years -) 5 males, and 5 females
Ages 9 yrs. 3 months to 12 yrs. 1 month

Molfese et al, 2006

Word and non-word Reading task

Word & Non-word Reading Task

(12 Boxes labeled BAG, KAT, DAK, "+/+" and "?" In each box.)

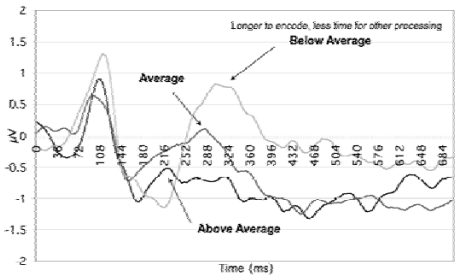
+	BAG	+	?
+	KAT	+	?
+	DAK	+	?

Molfese et al, 2006

Reading Ability & The Brain

Reading Ability And the Brain

(Picture of a line graph labeled Children Ages 9-12 years (n=27))



Children: Ages 9 - 12 years (n=27)

Molfese et al, 2006

Take away Message

Take Away Message

Automatic processing in normal readers – same brain areas involved trial to trial (stable, less effort, faster)

Struggling readers invent new ways to process from trial to trial (unstable, more effortful, slower)

Difficult for poorer performing children to make transition to more automated, consistent and faster processing

- Result is usually accurate decoding for simple tasks BUT at cost of poor fluency & comprehension

Impact of Brain organization on acquiring other skills

Impact of Brain Organization on Acquiring Other Skills

- Preschoolers differing in literacy skills were engaged in a brain study involving discrimination of shapes.
- Hypothesis- do children with different emergent literacy skills also exhibit differences in brain organization on an unrelated task?

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GET READY TO READ (GRTR)

Screening scale for 4 year olds
Child points to one of four pictures in response to a question
Taps
- Phonological skills
- Letter/sound/ word recognition
- Literacy (book knowledge, writing conventions)

http://www.getreadytoread.org/

Screening scale for 4 year olds
Child points to one of four pictures in response to a question
Taps
phonological skills
Letter/sound/word recognition
Literacy (book knowledge, writing conventions)

Mallasa et al, in press

Shape Matching Task
same different

Shape Matching Task

Same **Different**

Mallasa et al, in press

Take Away Message

Take Away Message

- Differences in speed of processing – ½ sec difference between when brain responses occur for children with different prereading skills when making shape judgments!
- Prior experiences (learning) change the brain's organization so that new tasks and skills are mastered differently and engage different brain networks.

Differences in speed of processing – 1/2 sec difference between when brain responses occur for children with different prereading skills when making SHAPE judgements!

Prior experiences (learning) change the brain's organization so that NEW tasks and skills are mastered differently and engage different brain networks

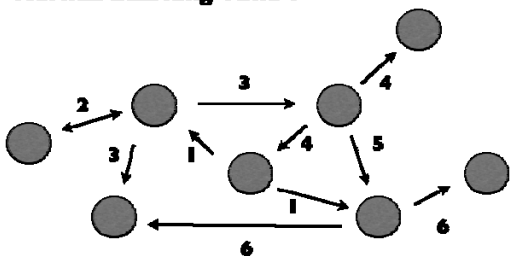
Brain Model For Concept and Skill Acquisition

Brain Model For Concept & Skill Acquisition

Normal Reading Development

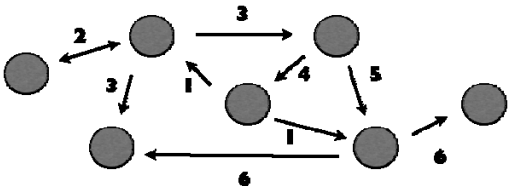
Normal Reading Development
Normal Learning Time 1 (Picture of group of circles with arrows pointing to and from each other with numbers 1-6.)

Normal Learning Time 1



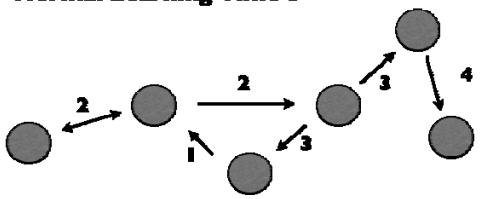
Normal Learning Time 2 (Picture of group of circles with arrows pointing to and from each other with numbers 1-6.)

Normal Learning Time 2



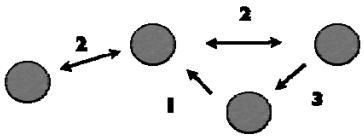
Normal Learning Time 3 (Picture of group of circles with arrows pointing to and from each other with numbers 1-4.)

Normal Learning Time 3



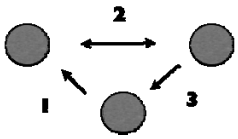
Normal Learning Time 4 (Picture of group of circles with arrows pointing to and from each other with numbers 1-3.)

Normal Learning Time 4



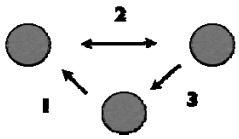
Normal Learning Time 5 (Picture of 3 circles with arrows pointing to and from each other with numbers 1-3.)

Normal Learning Time 5



Normal Learning Time 6 (Picture of 3 circles with arrows pointing to and from each other with numbers 1-3.)

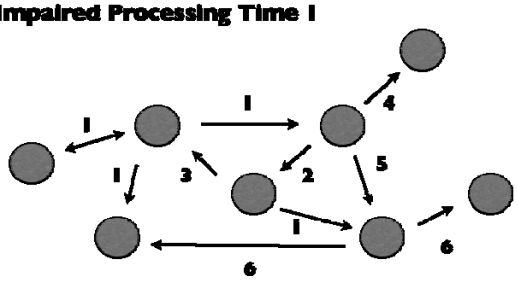
Normal Learning Time 6



At Risk Reading Development

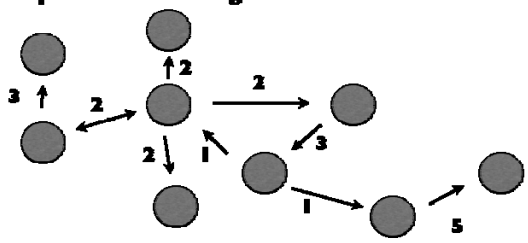
At Risk Reading Development
Impaired Processing Time 1 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-6.)

Impaired Processing Time 1



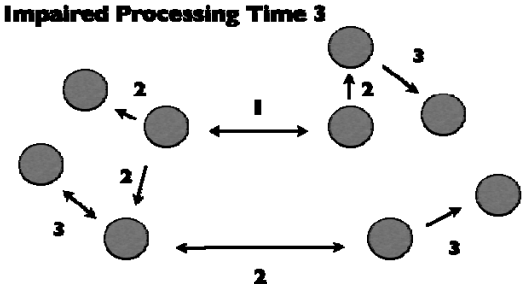
Impaired Processing Time 2 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-3 and 5.)

Impaired Processing Time 2



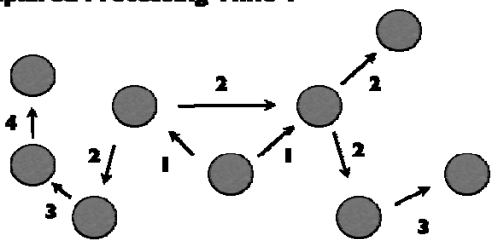
Impaired Processing Time 3 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-3.)

Impaired Processing Time 3



Impaired Processing Time 4 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-4.)

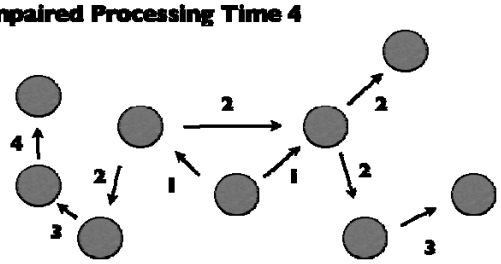
Impaired Processing Time 4



No Transition to Fewer Areas Engaged, With Predictable Temporal Links Between Areas

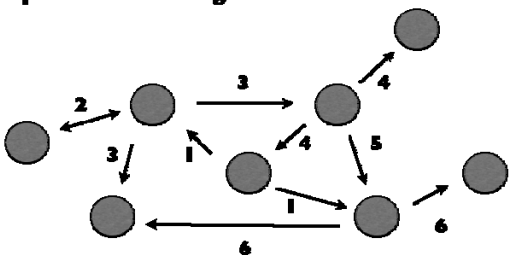
No Transition to Fewer Areas Engaged with Predictable Temporal Links Between Areas
Impaired Processing Time 4 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-4.)

Impaired Processing Time 4



Impaired Processing Time 5 (Picture of a group of circle with arrows pointing to and from each other with numbers 1-6.)

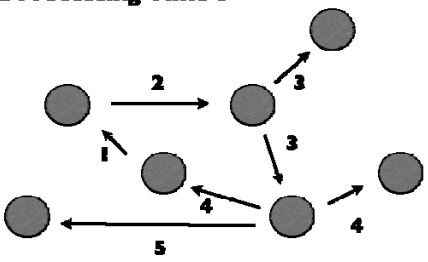
Impaired Processing Time 5



Impaired Processing Time 6

(Picture of a group of circle with arrows pointing to and from each other with numbers 1-5.)

Impaired Processing Time 6



The Learning Process & the Brain

The Learning Process & The Brain

- Initial Learning
  - Extensive but unstable multi-area involvement
  - Temporally disorganized
  - Slow
- Intermediate
  - Area involvement reduced but some instability
  - Temporal relationships more stable
- Expert Level
  - Further area reduction
  - Temporal and spatial relationships stable
  - Increased speed
  - Organizational flexibility

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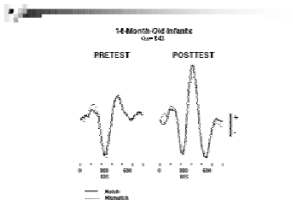
When to Intervene?
As Early As Possible

When to Intervene?

- Early Intervention should apply to all at risk for developmental disabilities.
- (Picture of two line graphs representing 14 month old infants.)

As Early As Possible

Early Intervention should apply to all at risk for developmental disabilities



10 min./day for 5 days

Implications- Brain Behavior Development

Implications - Brain-Behavior Development

Individual differences (resilience) impact behavior variations in response to environmental and neural factors

Different neural organizations can produce similar behavior patterns

Sensory information processing issues impact cognitive and neural development (which impact use of sensory information)

Individual differences (resilience) impact behavior variations in response to environmental and neural factors

Different neural organizations can produce similar behavior patterns

Sensory information processing issues impact cognitive and neural development (which impact use of sensory information)

Implications-Brain-Behavior Development

Implications - Brain-Behavior Development

Acquisition of new skills alters brain-cognitive organization and impacts:
- brain areas involved
- brain organization and efficiency for acquiring new skills

Environmental, physiological and cognitive changes impact Genetic expression (phenotype)

Work supported By:

- DOE 993511
- NIHR01 HL0100602
- NIH R01 DC005994
- NIH R41 HD 47083
- NIH R01 DA017863
- NASA SA42-05-018
- NASA SA23-06-015

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Questions???

QUESTIONS ???

tori@louisville.edu

dimolfese@mac.com

http://homepage.mac.com/dimolfese/