In Honor of Jeanne Dise-Lewis, Ph.D.

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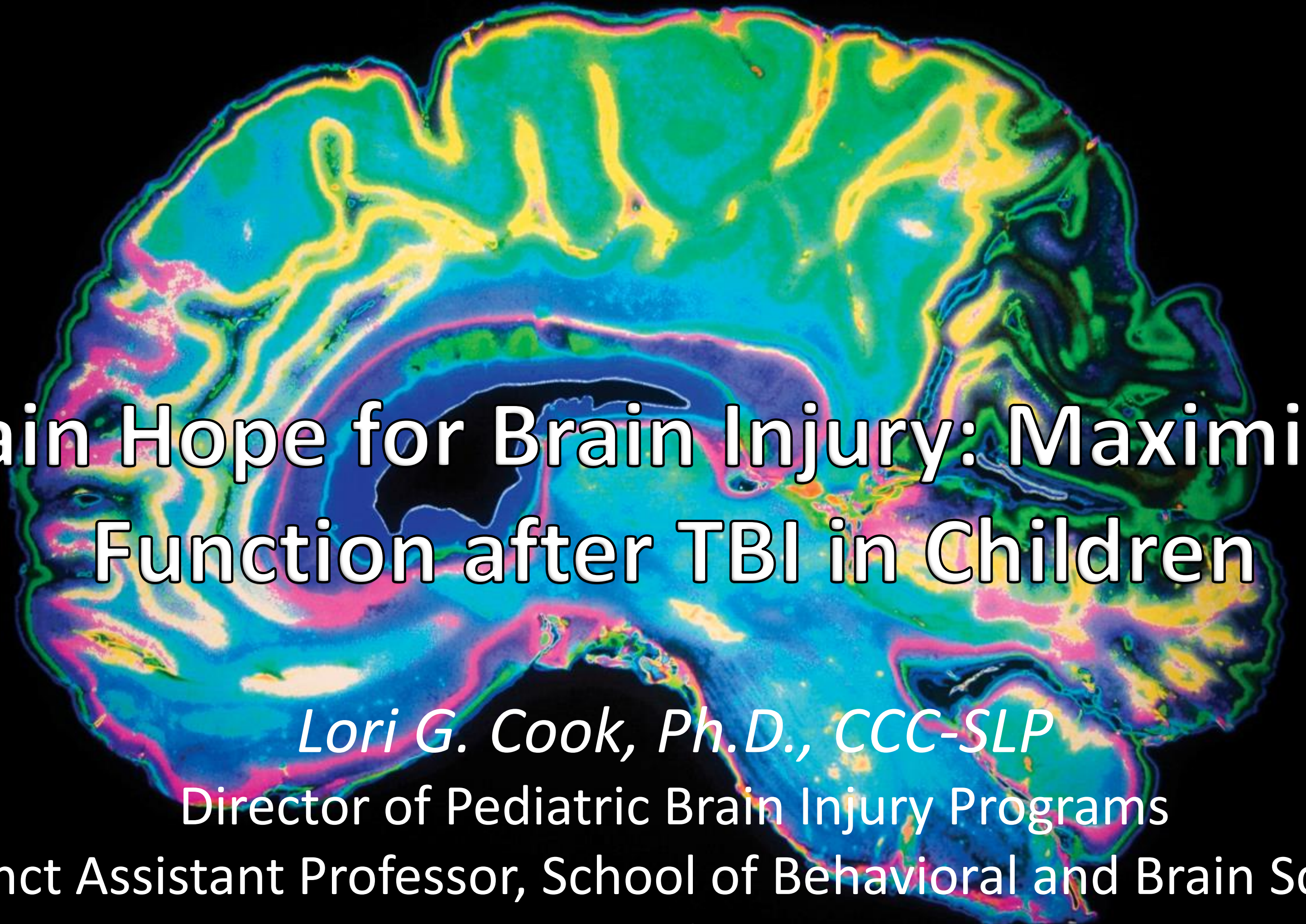

Brain Hope for Brain Injury: Maximizing Function after TBI in Children

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Center for BrainHealth—The University of Texas at Dallas

Scientific research institute committed to enhancing human cognitive potential

Dedicated to understanding, protecting and healing the brain

Greatest asset

Ability to extract complex meanings, learn, remember, reason, generate new ideas, innovate and solve novel problems

Complex cognitive focus

Discover ways to advance complex cognitive capacity, not isolated processes

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OUR MISSION

Maximize
brain performance
in people of all ages
& conditions.

HEALTHY ADULTS

BRAIN INJURY

Traumatic Brain Injury
Concussion • Stroke
Tumor • Chemo Brain

BRAIN DISEASE

Alzheimer's/Dementia
Post Traumatic Stress Disorder
ADHD • Addiction • MS • Bipolar
Depression • Autism/Aspergers

CORPORATIONS

ATHLETES

of all ages

STUDENTS, TEACHERS & PARENTS

MILITARY

Veterans &
Active Duty

BRAIN
PERFORMANCE
INSTITUTE
at Center for BrainHealth®

Unraveling Complexities of Brain Health and Repair

Recognizing that not all cognitive activities are equal – many do not transfer to untrained or functionally meaningful areas

Discovering brain mechanisms that support improvement with complex cognitive engagement

Pushing the limits of brain plasticity in brain injury, disease, and even healthy aging

Impact of Brain Injury on the Developing Brain

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Brain Injury in the United States

- Every 15 seconds, a U.S. citizen sustains a brain injury (approx. 1.4 million people each year)—up to 3.8 million if factoring in mild brain injury
- 1 in 30 children will sustain a brain injury before age 21
- TBI is the most common cause of death & disability among children in the U.S.

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What can affect performance on the road to recovery?

- Long-Term Effects
- Delayed Onset of Deficits
- Age Variability

Peak in Adolescence

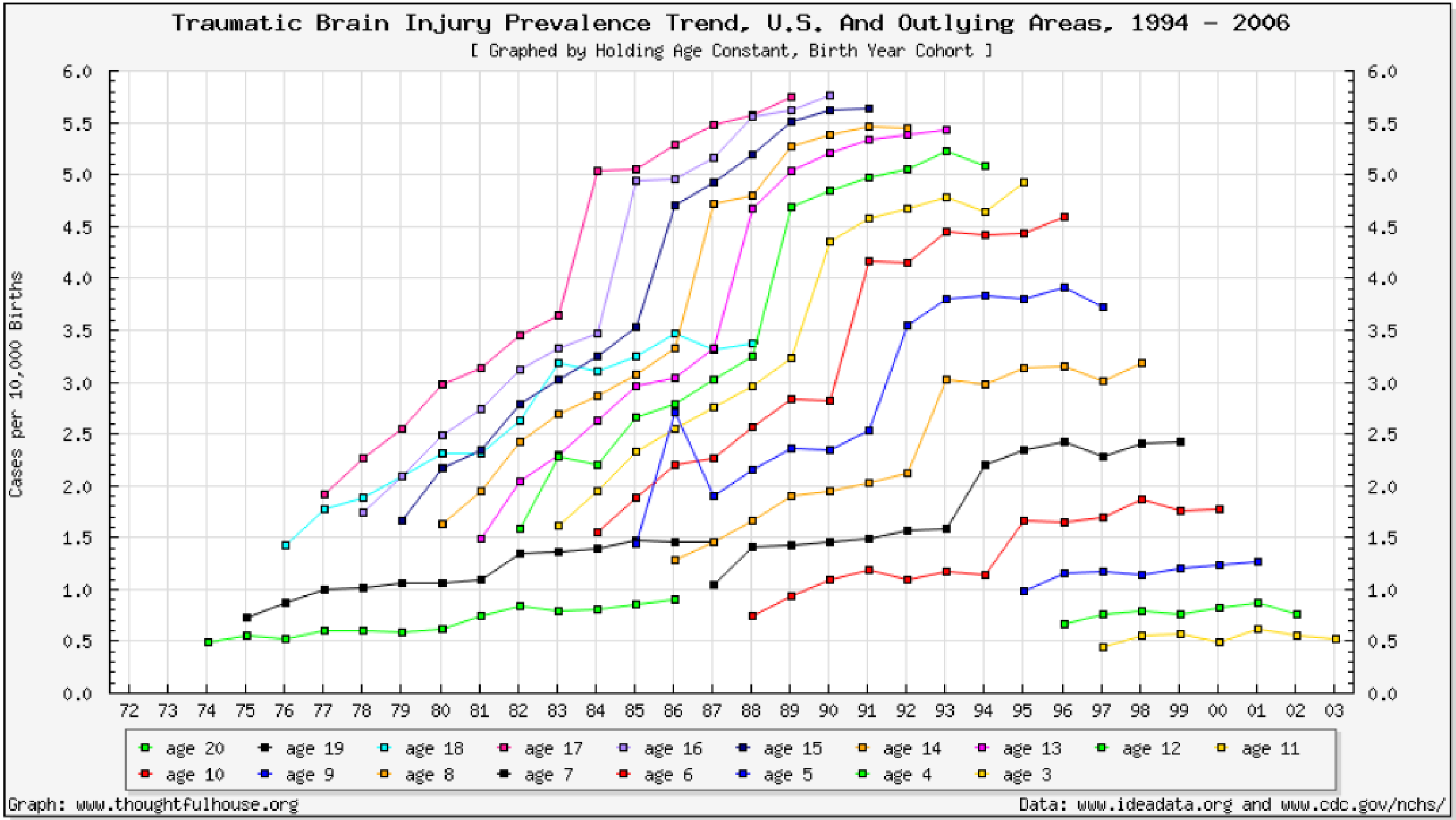

Figure 3: CDC Figures for TBI Prevalence by Age

(Faul et al., 2010)

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Typical follow-up for pediatric brain injuries

- Days to weeks in hospital ward
- Several weeks in rehabilitation
- Recommendations to schools
- Little additional follow-up care

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Pediatric Brain Recovery

1. Prognosis for functional recovery of *old* skills is better in early brain injury

2. Prognosis for acquiring *new* skills after injury is worse after early brain injury

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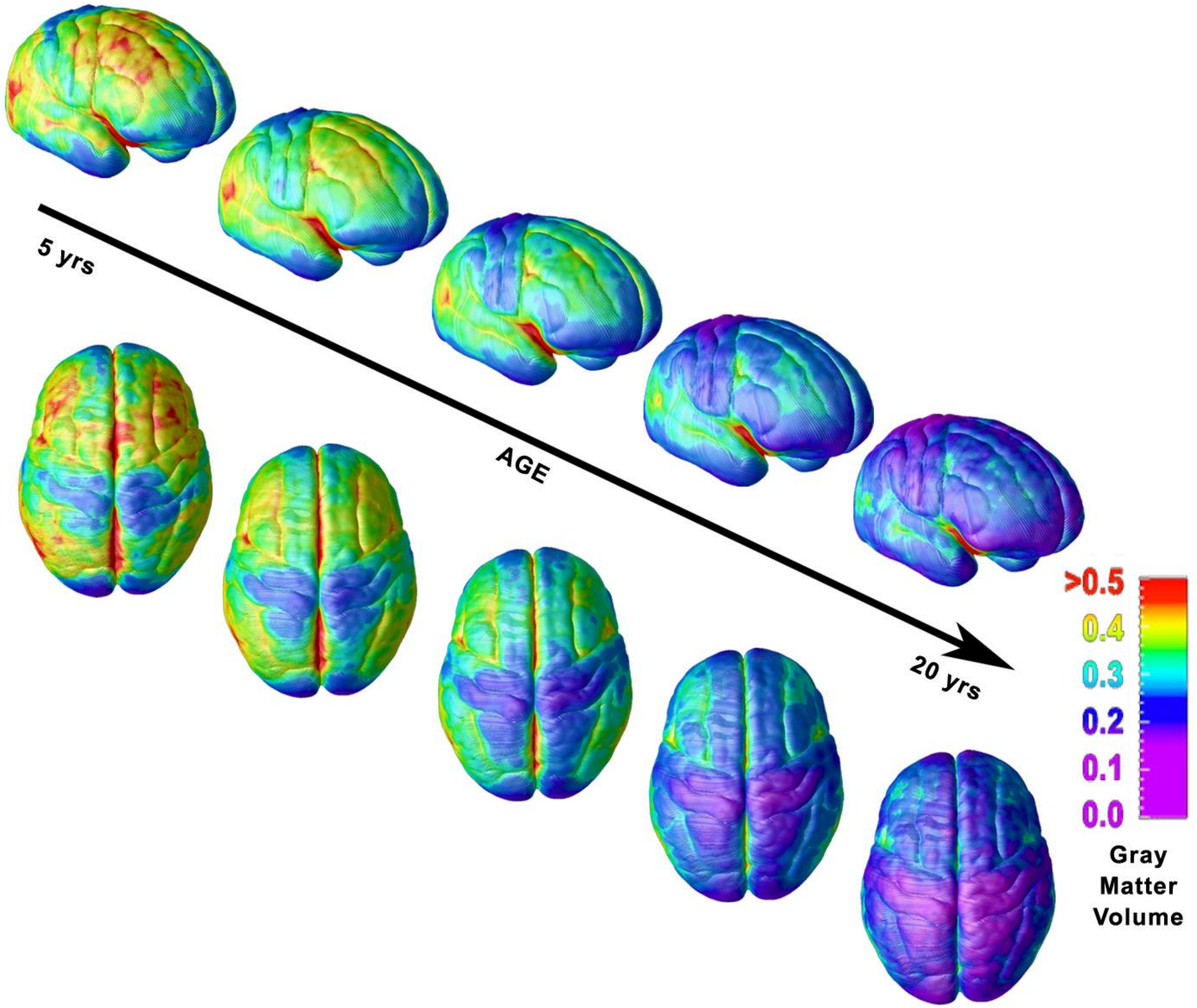
Mapping of human brain from childhood to early adulthood



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Box 2. Structural architecture of the developing brain

The human brain undergoes dramatic changes in both its structural architecture and functional organization that reflect a dynamic interplay of simultaneously occurring progressive and regressive events. Although the total brain size is about 90% of adult size by age 6 years, the brain continues to undergo dynamic changes throughout adolescence and well into young adulthood [61]. Figure I illustrates some of these developmental changes, including proliferation and migration of cells mostly during fetal development [62,63], regional changes in synaptic density during postnatal development [11,12,64], and protracted development of myelination well into adulthood [65]. Current non-invasive neuroimaging methods do not have the resolution to delineate which of these processes underlies observed developmental changes beyond gray and white matter subcomponents.

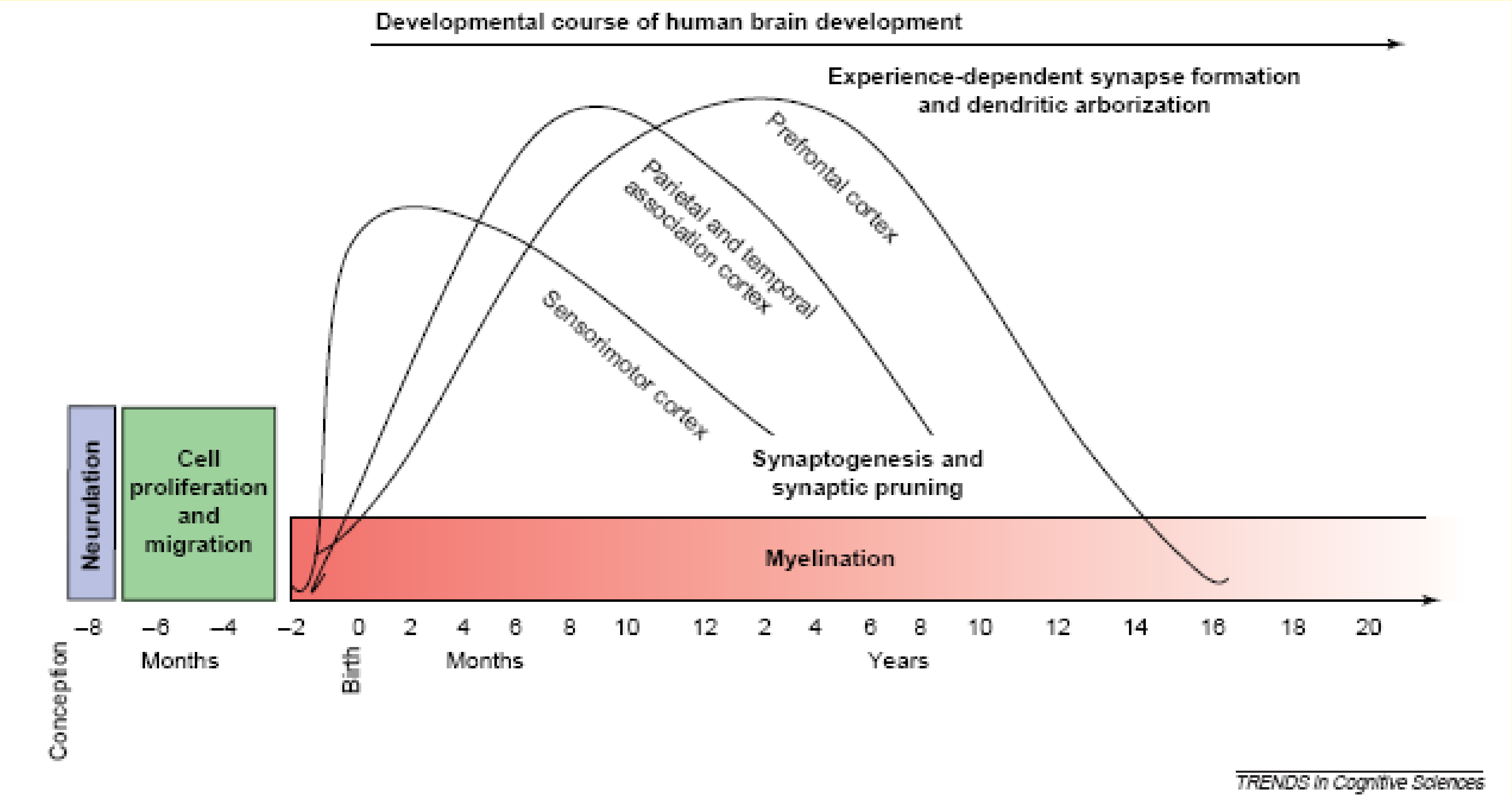
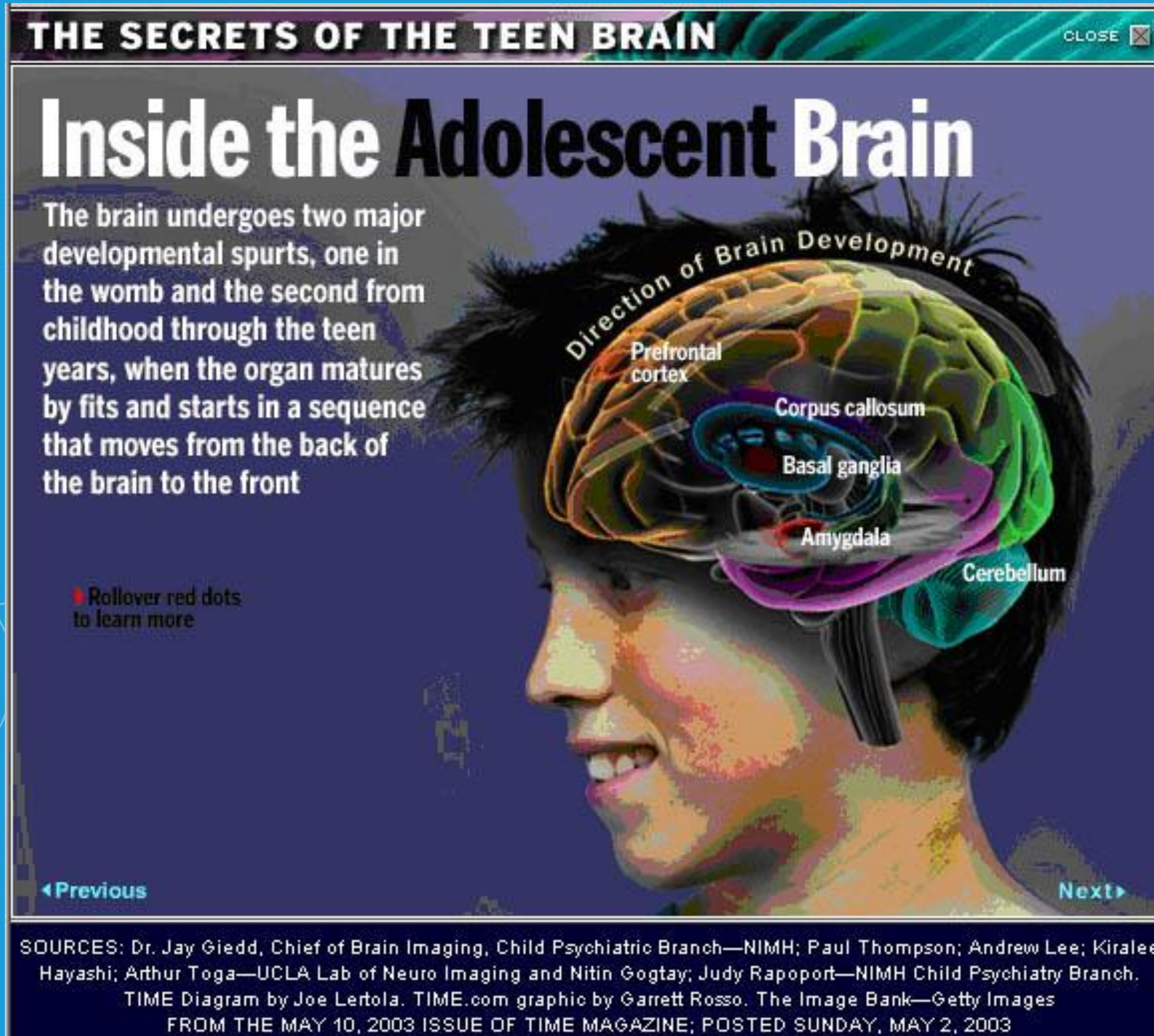


Figure I. See text for details. Adapted with permission from Ref. [66].

Thompson & Nelson, 2001, Am. Psychol



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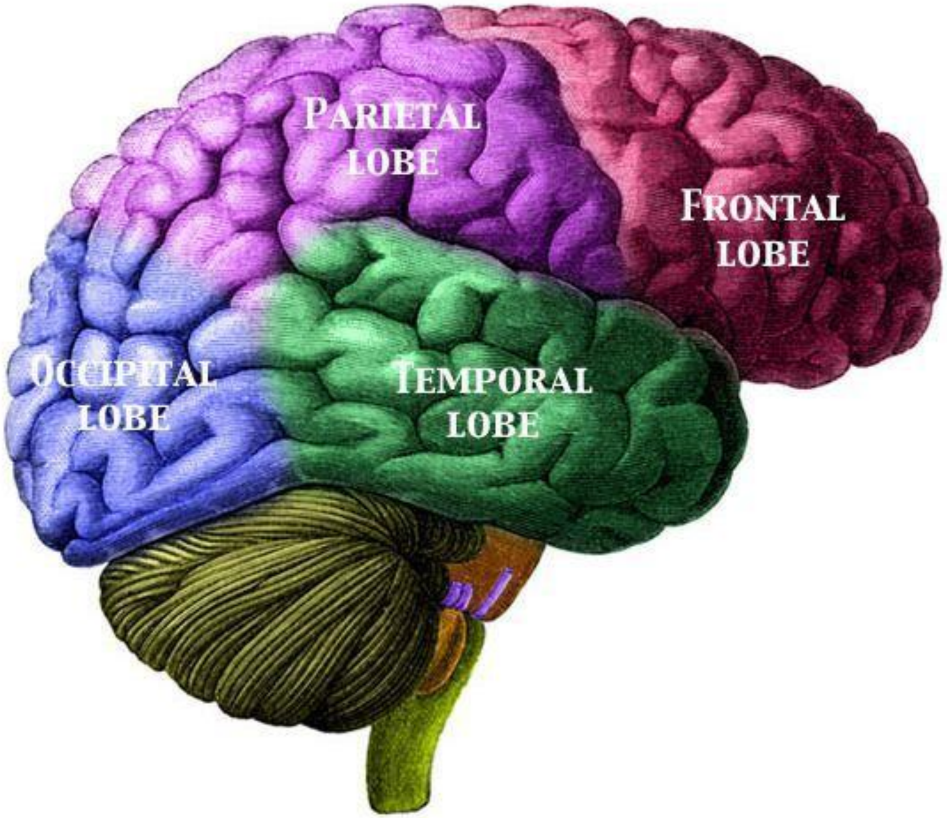
The Adolescent Brain

“High Horsepower, No Steering”

- Hormone Changes
- Emotional Brain
- Brain’s reward system
- Frontal Lobe Development
- Synaptic Pruning

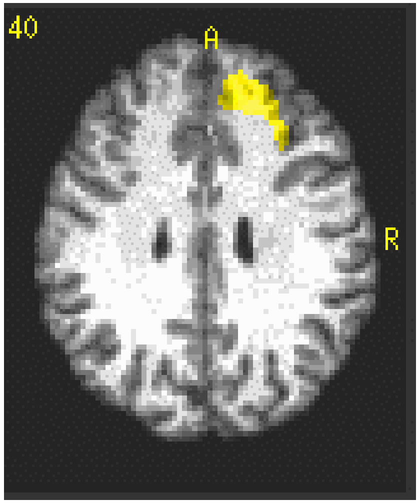


Importance of frontal lobes

The brain undergoes significant changes in adolescence (rapid growth from ages 13-25)

The most significant brain changes occur in the frontal lobes

The frontal lobes allow us to make sense of the massive amount of information flooding our brain constantly



Pediatric Brain Recovery

- Often fall behind in middle school
- Traditional cognitive measures insensitive
- Recover basic intellect
- Recovery is not a one-time phenomenon

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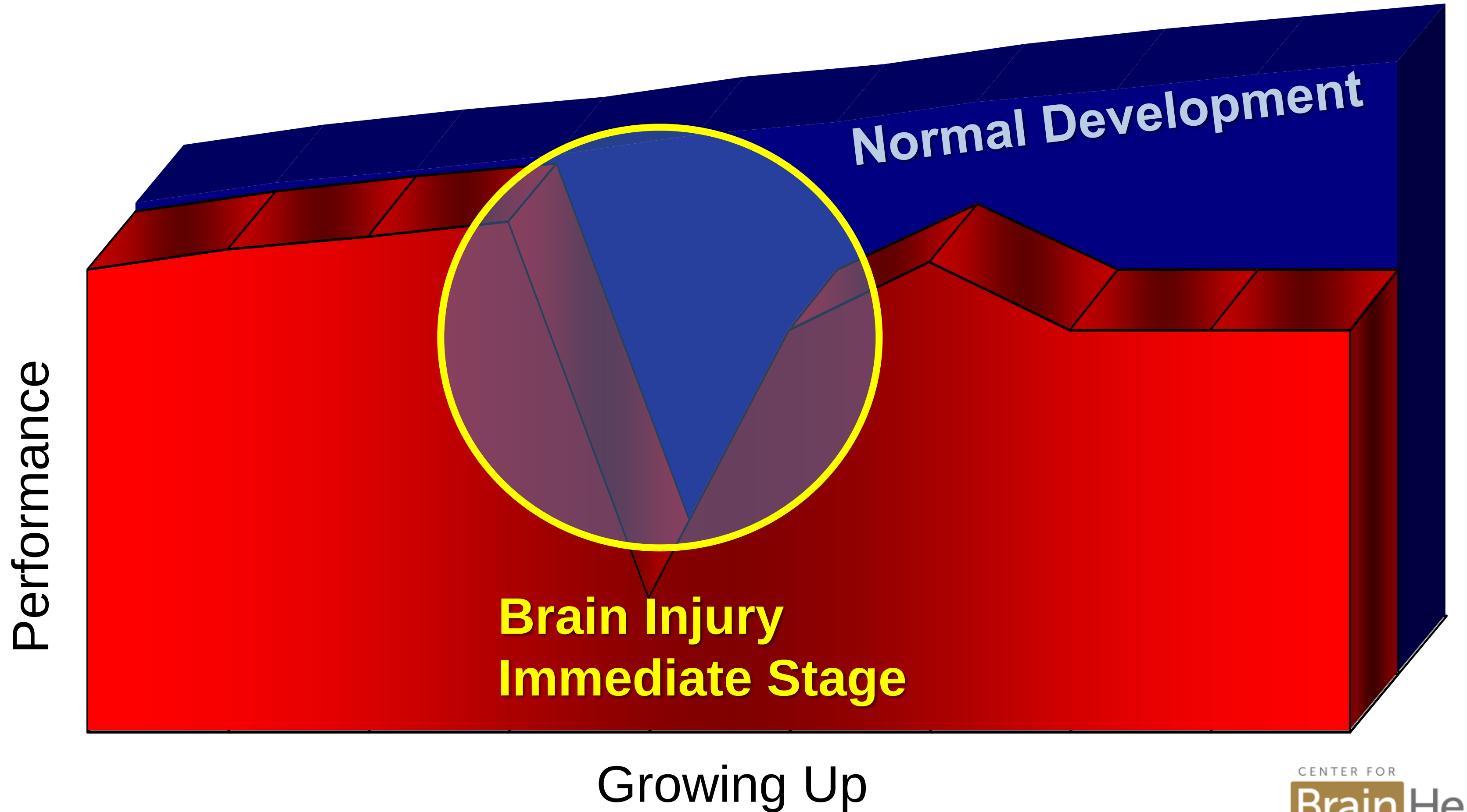
Pediatric TBI: Immediate Phase of Recovery



Chapman, 2006, Brain Injury Professional

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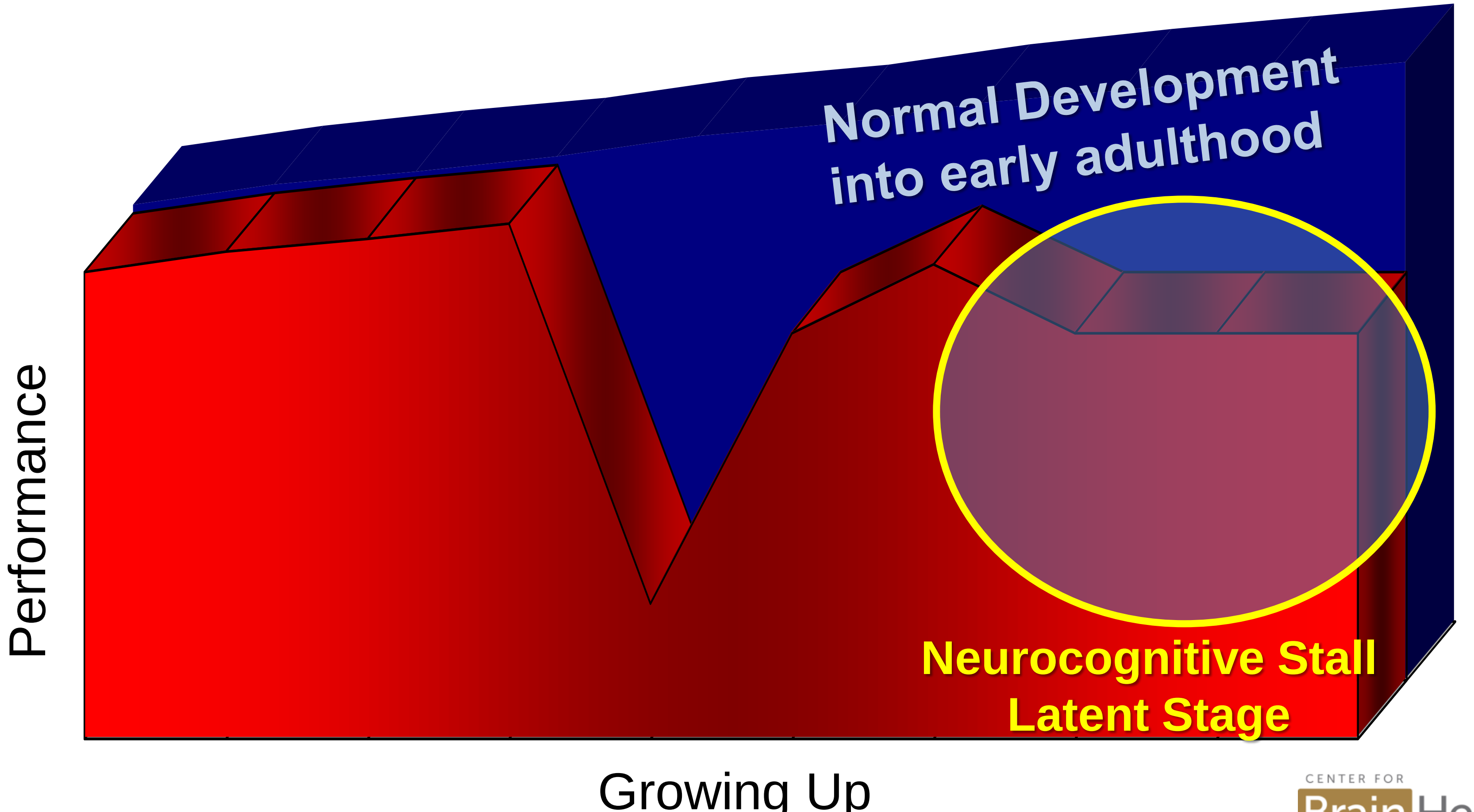
Neurocognitive Stall

Pediatric TBI: Latent Phase of Recovery



Chapman, 2006, Brain Injury Professional

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Child TBI: Dramatically Different from Adults

- Some impairments may get worse over time
- New difficulties often emerge years later
- Children have to recover at each new stage of development

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“At this latent stage post injury, the travesty is that no link is made between later emerging cognitive problems, i.e., neurocognitive stall, and a brain injury which occurred 2, 5, or even 10 years earlier.” --Sandra B. Chapman (2006)

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Detecting & Monitoring Later-Emerging Deficits

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Pediatric Traumatic Brain Injury (TBI) Research

NIH R01 study: *Neurobehavioral and Social Outcome of Head Injury in Children*—P.I. Dr. Harvey Levin (Baylor College of Medicine)

- Recruit children/adolescents at time of injury (across severity levels)
- Evaluate at baseline and at various time points longitudinally
- Most recent focus on executive functions serving social cognition
- Brain imaging component (MRI, fMRI, DTI, ASL)

Neurobehavioral & Social Outcome of Head Injury in Children

- Executive Functioning
- Discourse and Strategic learning
- Social Cognition
- Motivation
- Academic Achievement
- Psychiatric & Behavioral Issues

ADHD & TBI

Almost one third of children with severe TBI develop ADHD secondary to brain injury.

Predictors:

- Severity of injury
- Pre-injury behavior problems

The combination of severe injury and secondary ADHD predicted poor inhibition.

Source: Schachar, R et al. (2004)

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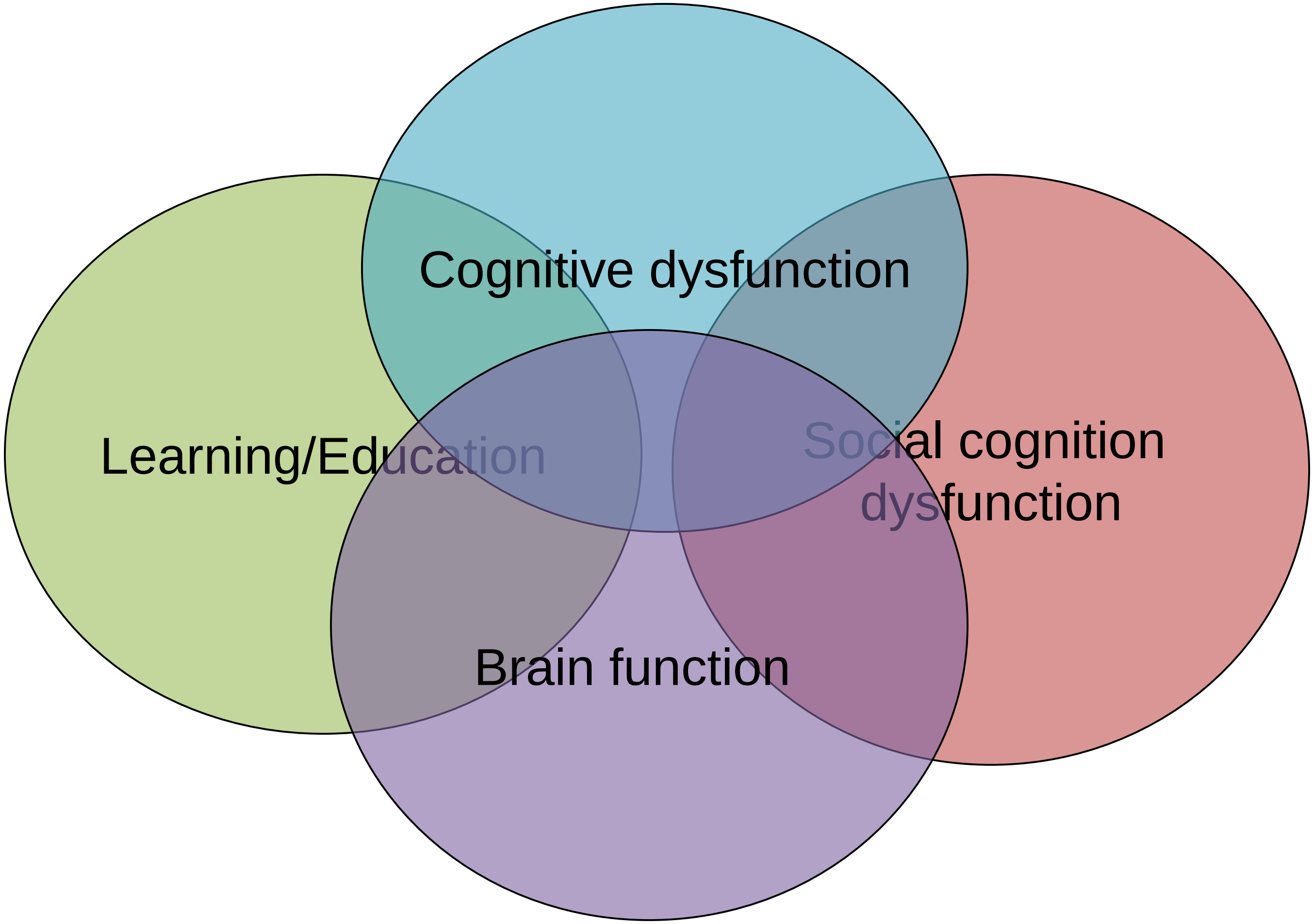
Consequences of Pediatric Brain Injury

- Inefficient discourse processing—gist vs. details
- Decreased problem solving skills
- Impaired Motivation and response to rewards
- Impulsive behavior
- Prospective and working memory deficits
- Emergence of maladaptive behavior

Symptom Domains in TBI



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The Circle of Care

DePompei, 2003

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Executive Functions

Mental processes that direct thoughts, action, & emotion, particularly during active problem solving. Specific skills include:

1. *Selecting appropriate goals for a task*
2. *Planning & organizing an approach to problem solving*
3. *Initiating a plan*
4. *Inhibiting distractions*
5. *Holding a goal & plan in mind*
6. *Being flexible by trying a new approach when necessary*
7. *Monitoring to see that the goal is achieved*

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Executive Function Evaluation

- *Parent and teacher forms of the BRIEF (Behavior Rating Inventory of Executive Function)*
- *Tests of working memory (N-back, etc.)*
- *Tests of inhibition (Stroop, Go/No-Go, etc.)*
- *Tests of problem-solving (Tower of London, etc.)*
- *Iowa Gambling Test*
- *Metacognitive tasks (Judgment of Learning, etc.)*
- *Self-Regulation during Naturalistic Action (Birthday Task)*

(Levin & Hanten, 2005, Pediatric Neurology)

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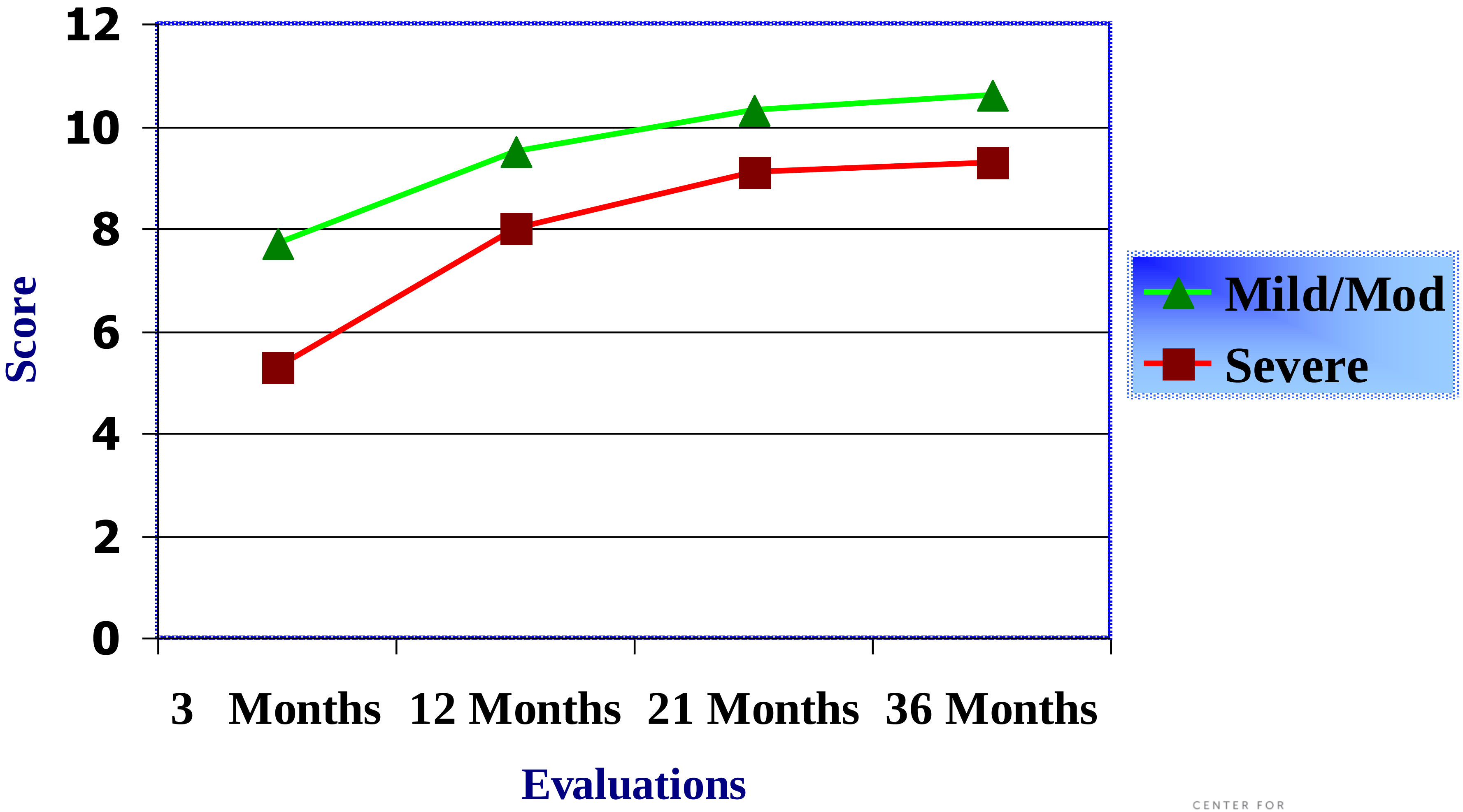
Factual Retrieval of Details



(Chapman et al., 2004, Dev Neuropsych)

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N-Back Working Memory Tests

Letter Identity

Letter Rhyme

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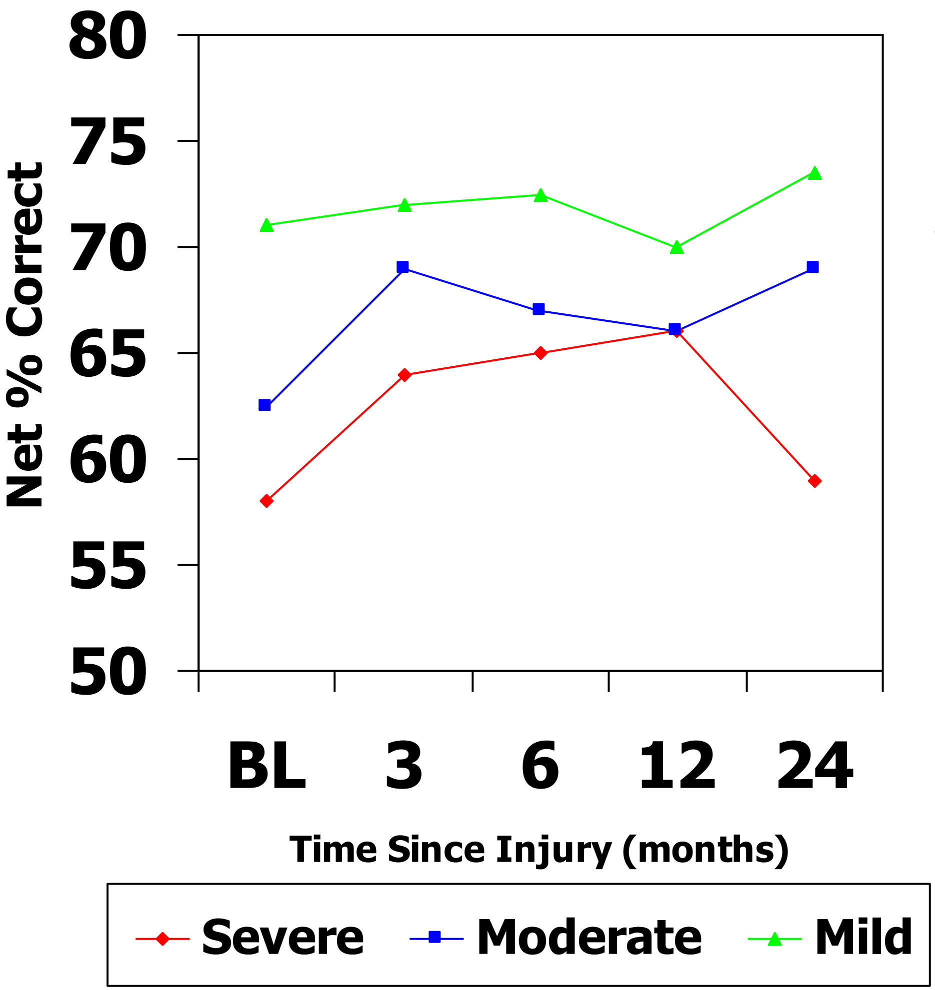
N-Back Working Memory Test



Working memory performance for severely injured children declined from the 12-24 month period, in contrast to the mild & moderately-injured groups.

(Levin et al., 2004)

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Strategic Learning and the Brain

- One of the most impressive and important brain functions underlying learning
- Extracting **important** information while inhibiting **unimportant** information
- Turning explicit details strategically into abstract meanings

Strategic Learning and the Brain

The brain is most effective at abstracting meaning and not at storing details

(Brainerd & Reyna, 1998; Gabrieli, 2004)

The important part of learning is **NOT** about "how much you learn"

But rather:

1. How efficiently you **extract** the main point or central message *(Gabrieli, 2004)*
2. How efficiently you **exclude** irrelevant information so you do not use up vital storage capacity *(Vogel et al, Nature, 2005)*

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Significance of Strategic Learning

Forming bigger ideas and suppressing irrelevant details helps you think faster and more efficiently

Remembering the “gist” of something is more resilient than remembering details—actually continues to improve with age

Pulling out the gist does not mean that you:

- Do not attend to details
- Process information less thoroughly

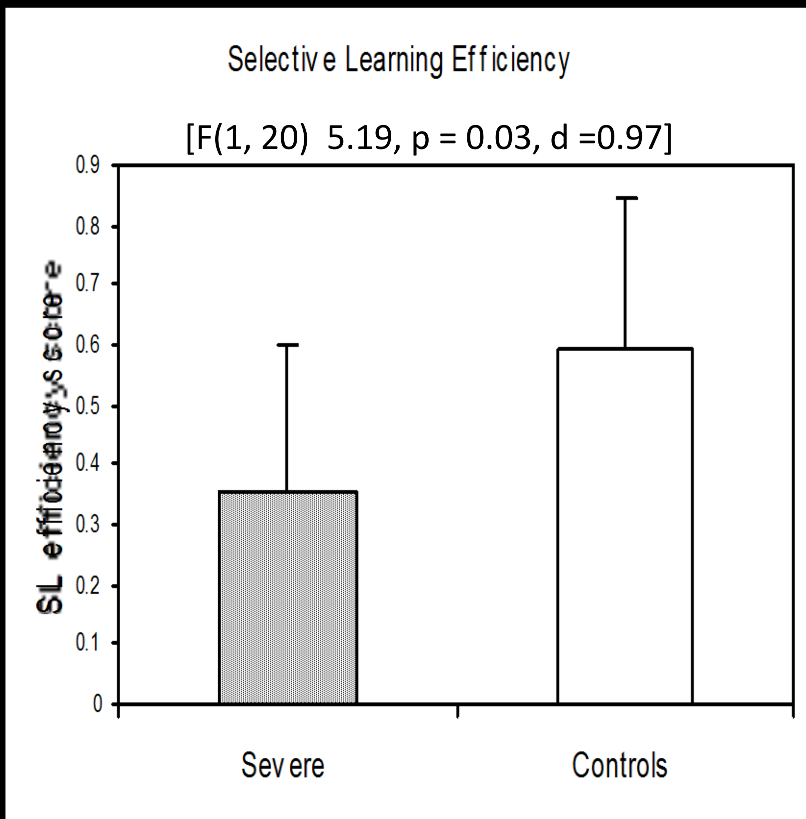
Characteristics of Strategic Learning: PICK

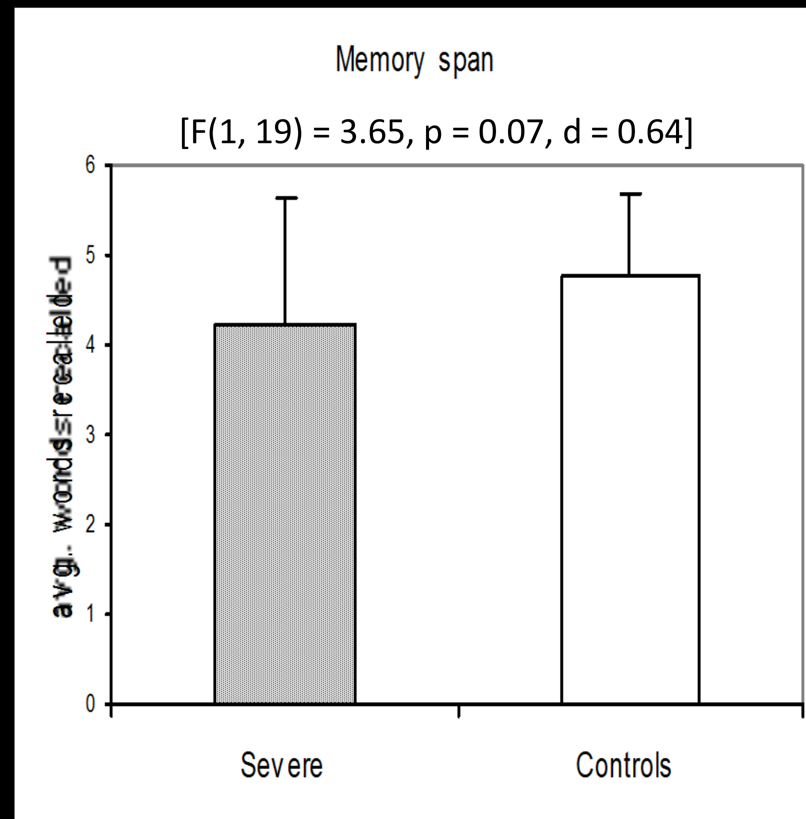
- **P**rioritizing important information
  - *7 – 8 Years Old*
- **I**nhibiting unnecessary detail
  - *9 – 10 Years Old*
- **C**ollapsing details into bigger ideas
  - *12 – 14 Years Old*
- **K**eeping abstracted meaning
  - *15 + Years Old*

Strategic Learning

- Focusing on specific, important information as designated by a particular assignment/goal
- In order for strategic learning to occur, a child must:
  - Inhibit unimportant information
  - Select important information
  - Use working memory skills to retain important information
  - Use self-monitoring skills to check his/her performance

Selective learning efficiency and memory span for children with severe TBI and control children on Selective Learning with Auditory Lists



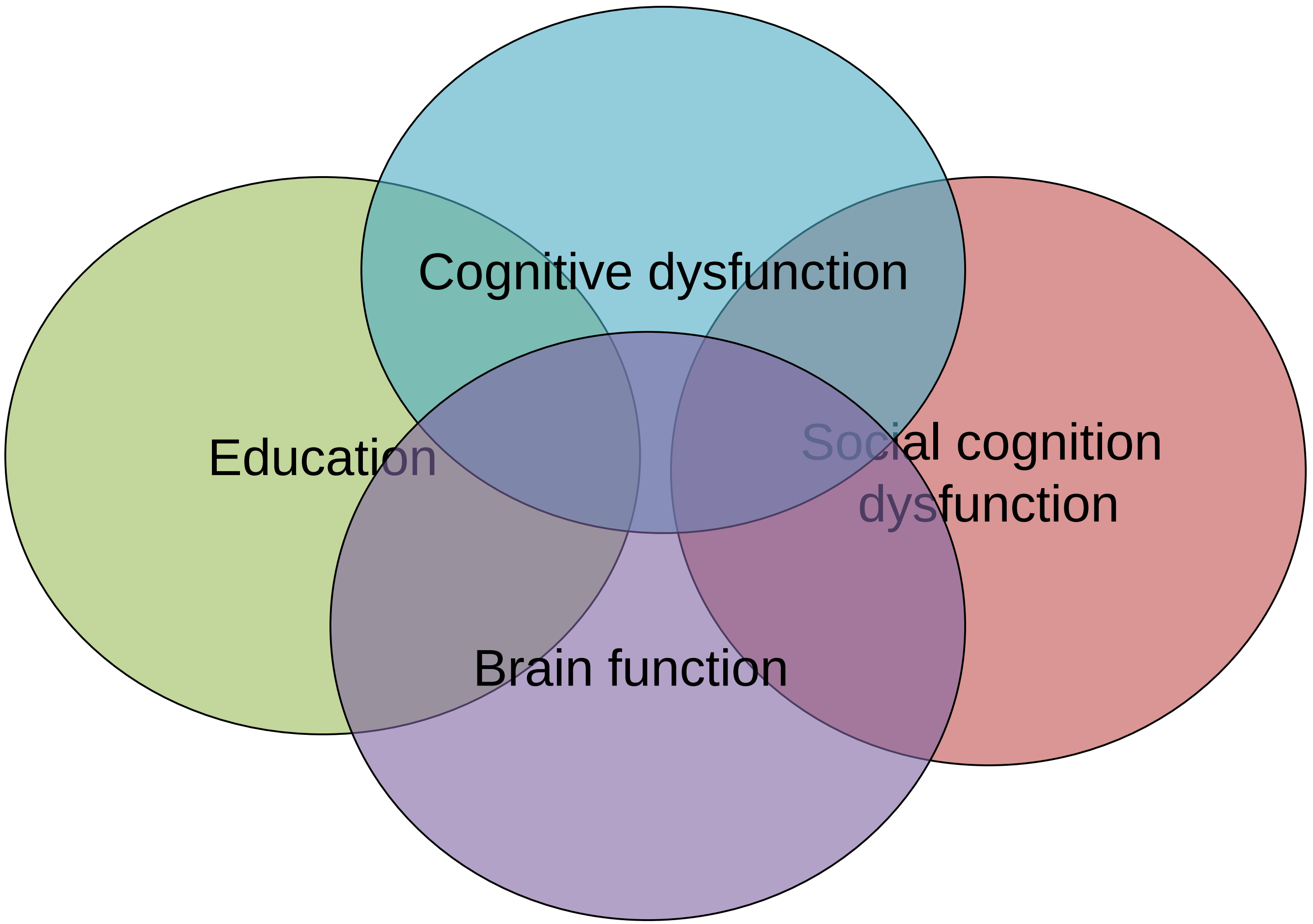


(Hanten, Chapman, et al., 2004, Ann. Neurol.)

Prioritizing high-value information over low-value information

[Feebo]

Symptom Domains in TBI



Social Cognition

The cognitive skills that allow us to interact with others

Involves a vast set of abilities:

- *Self-regulation of emotions/responses*
- *Perceiving other's emotions*
- *Social knowledge and application*

Symptom impact

- School drop out
- Depressed, some suicidal
- Delinquency
- Unemployment
- Broken relationships

Virtual Interpersonal Negotiation Strategies (vINS) Task *(Hanten et al., 2011)*

- Each child administered 6 scenarios total (3 peer-peer & 3 child-parent interactions) of varied levels of processing load
- Instructions:

"In this task you will watch a video about two people having a problem. Listen carefully. After each video, I will ask you some questions about that problem and how to solve it."

- What is the problem here and why?
- How do you think Caleb feels and why?
- How do you think his dad feels and why?
- What is something you can think of that Caleb can do to solve his problem with his dad?
  - *How would that solve the problem?*
- What else could he do?
  - *How would that solve the problem?*
- Can you think of anything else?
- What would be the best way for Caleb to solve his problem with his dad?
- How would Caleb and his dad feel if Caleb did that and why?
- What do you think the best possible outcome would be?

vINS Scoring

- Impulsive (physical only) = 1
- Unilateral (one-sided) = 2
- Reciprocal (two-sided) = 3
- Collaborative (mutual goals/long-term effects)= 4

Levels Categories	Impulsive = 1	Unilateral = 2	Reciprocal = 3	Collaborative = 4
Defining the problem	Physical terms, no psychological states	Mentions only self <u>or</u> other's wants/needs	Mentions both self <u>and</u> other's wants/needs	**Mutual goals & long-term relationships**
Generating strategies	Physical, with little difference between impulse and action	Emphasize assertion of power or appeasement, conformity	Satisfying both participants in a "just' fashion	**Collaboration with shared goals**
Selecting specific strategy	Selected to immediately gratify or protect self	Chose to please self <u>or</u> other in the short-term	Selected to satisfy self <u>and</u> other	**Chosen to optimize sense of collaboration and sustain relationship**
Evaluating Outcomes	**Based on immediate needs of self**	**Based on personal satisfaction of either self <u>or</u> other**	**Based on balance (self <u>and</u> other) with emphasis on a fair exchange**	**Based on long-term effects of relationship**

vINS Pilot Results

- Youth with TBI significantly poorer overall in all 3 processing load conditions
- Differences more pronounced with increased processing load
- Group differences apparent even at the initial stage of problem-solving (defining the problem)
- Groups differed most promininently in relation of overall score to cortical thickness in the right medial orbitofrontal region and the cuneus

(Hanten et al., 2011, Neuropsychologia)

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Virtual Reality—Predicting Outcomes Task

- Each child administered 4 scenarios total
  - *2 scenarios "setting up" a decision*
  - *2 scenarios including both the set up and decision made*

- Represent either legal or moral infractions

(Cook et al., 2013, JINS)

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Set-up Only Scenarios

“What do you think will happen?”

Scored according to the number of actions and reasons for those actions provided by the child

Setup + Outcome Scenarios

"What are the consequences for the decision that was made?"

Scored according to the number of short-term (immediate) consequences and long-term consequences provided by the child

Predicting Outcomes Pilot Results

- No group differences for number of actions predicted or reasons provided (although trend for the latter) & similar numbers of short-term consequences given
- The non-injured youth offered more long-term consequences *(p = .010, d = 1.22)*
  - *Group differences more pronounced for social dilemmas of a moral nature*
- For overall score, stronger relations for TD group to thickness of right medial prefrontal cortex/frontal pole and precuneus

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Strategic Learning through Gist Reasoning

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Test of Strategic Learning (TOSL)

- Involves reading three narratives of increasing difficulty
- Discourse skills assessed include the following:

1. *Summary (Using own words, globalizing/gist, inferencing, organization)*
2. *Lesson/Moral (abstract, expected moral)*
3. *Explicit & Implicit Content Probes (recall of factual and inferential information)*
4. *Recognition of Important vs. Unimportant Information*

Gist Reasoning vs detail processing (Gamino, Chapman, & Cook, 2009)

- 20 Children with moderate/severe TBI and 20 age- and SES-matched TD controls ages 10-15 yrs

- Assessed on Test of Strategic Learning

- TBI group demonstrated:
  - *Significant impairment in ability to abstract gist-based meaning*
  - *Relatively preserved ability to recall and encode details from text*

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Summary of findings in Pediatric TBI (cont'd)

- Marked deficits in combining detail information into more generalized gist meanings (Chapman et al., 2004)
- Predominant use of an immature strategy to reduce information by deleting information (Chapman et al., 2006)
- Youth with TBI condensed text to the same degree as controls but simply retold explicitly stated ideas without forming gist-based concepts (Chapman et al., 2006)

Gist vs. memory *(Chapman et al., 2006)*

- Both mild and severe TBI demonstrated gist impairment relative to non-injured controls

- Working memory (n-back task) impaired in severe TBI

- Both groups comparable to control on immediate memory measure (CVLT)

- Working memory found to be related to gist reasoning ability

Suspected Problems in TBI

- Too much selection – too little inhibition
- Low efficiency of prefrontal neural connections
- Stuck on more bottom-up processing
  - Good recovery of straightforward information recall
  - Higher-order functions required to strategically learn new information may continue to be at risk

“Treatment seems backwards”

“We were surrounded by help when the brain was undergoing spontaneous recovery.

There was NO help when we and our child’s brain needed treatment the most ...years later.”

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Neuroplasticity:
The Hope of Restoration, Regeneration, and Resilience

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Recent Discoveries in Brain Research

The Good News:

- The brain continues to make new cells throughout our life
- The brain has the capacity to reorganize, forming new connections and strengthening weakened neural pathways (learning)
- New, sophisticated brain imaging technology is making it possible to understand the brain's response to treatment

Imaging Advances

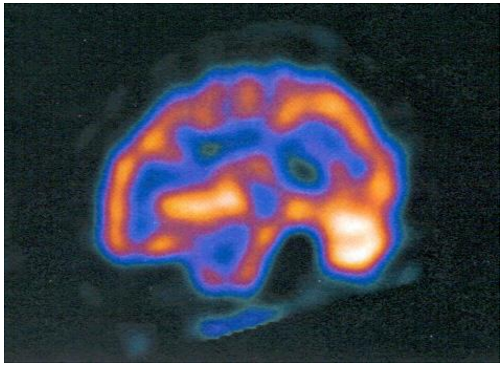
Functional Brain Imaging (EEG, fMRI) –

- Use of latest technology to measure baseline brain function and reconnection of brain networks after treatment

Brain Biomarkers –

- Markers in the brain that impact onset, progression, and recovery of brain disease including genes, hormones and neurotransmitters





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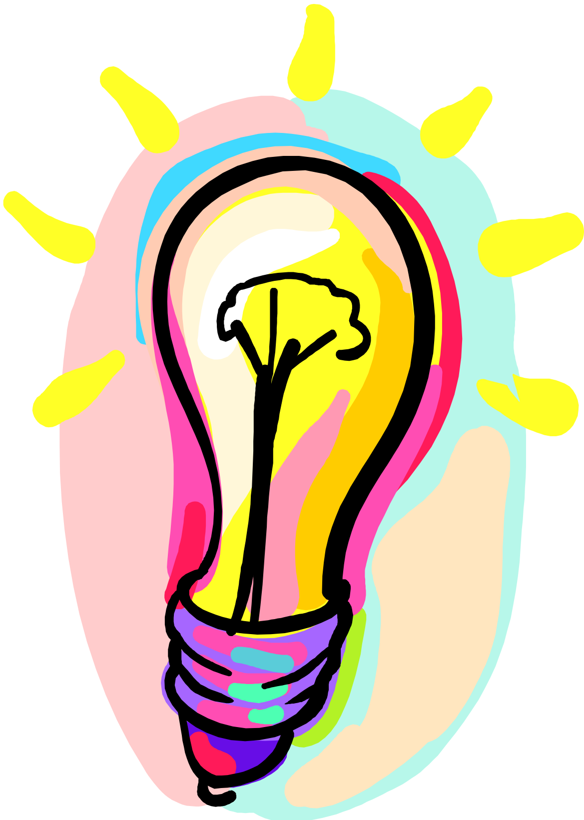
What can we do now? A lot.

- Research regarding brain plasticity provides much hope
- Treatment throughout the lifespan can continue to make new neural connections
- Improvements can be made in functional outcomes



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Focus on Frontal Lobes

Harnessing power of frontal lobes will lead to:

- *Increased brain potential*
- *Maximized brain efficiency*
- *Enhanced productivity*
- *Enriched creativity*
- *Greater innovation*

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Restorative Approach

What works:	What doesn't:
Active involvement/being engaged in something you like	Passive repetitive tasks – *automatic*
Being challenged –"sweating it"	Mere involvement with sensory input
Being strategic	Rote thinking

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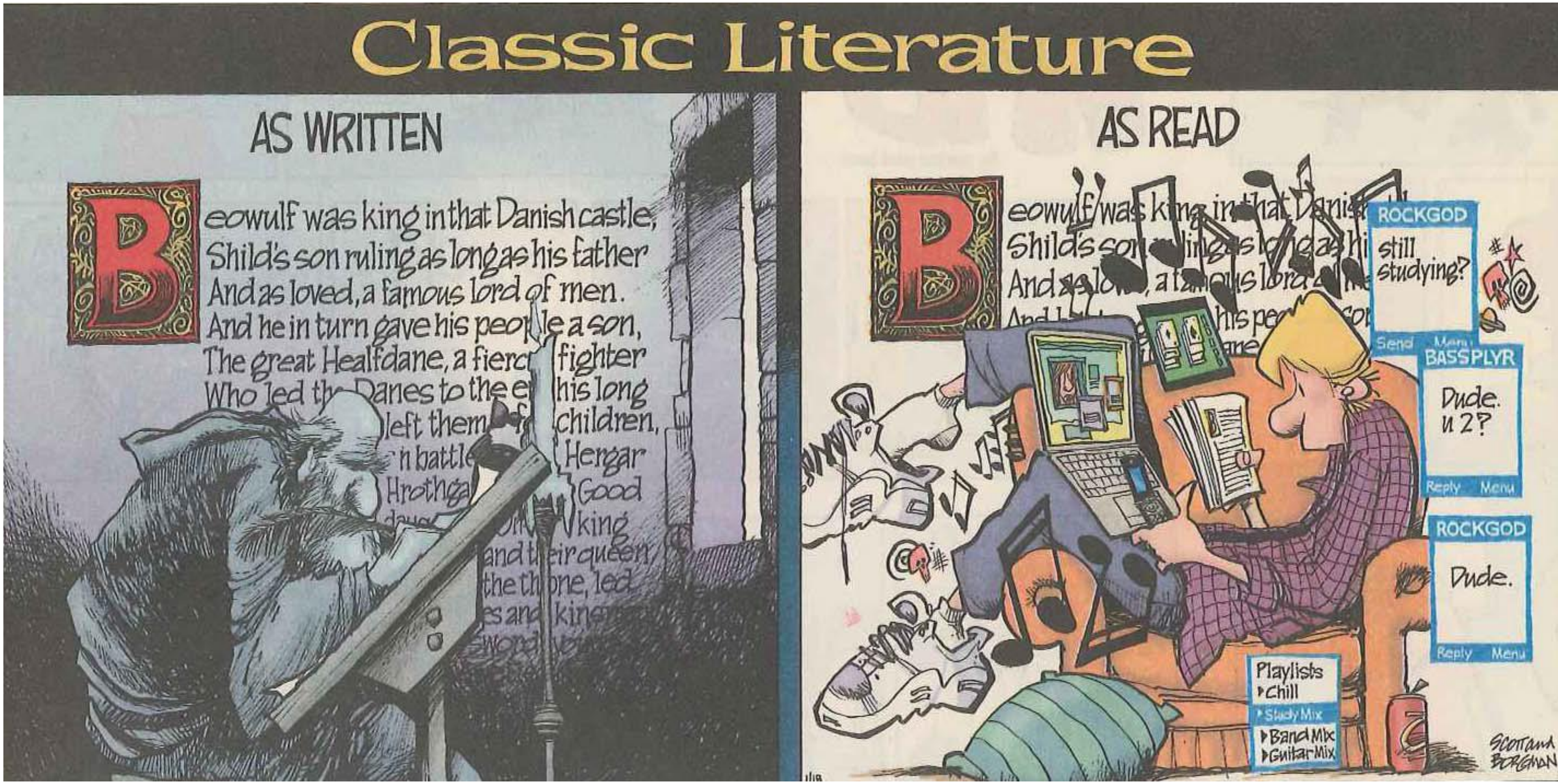
A Day in the Life



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Exercise Strategic Attention

2 The Brain Power of Two

Identify top priorities each day

1 The Brain Power of One

Do one thing at a time

0 The Brain Power of None

Take a break when you "hit the wall" mentally

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Strategic Learning: Getting the "gist"

Implementing a <u>strategic</u> approach to learning by:

1. extracting important information while inhibiting unimportant information,
2. holding key ideas in working memory, and
3. synthesizing information to form abstracted gist-based meanings through complex reasoning

(Cook, Vas, & Chapman, 2014; Gamino, Chapman, & Cook, 2009; Gamino et al., 2010)

Gist Reasoning Training: The Prior Evidence

- Has been shown to be effective for:
  - Children & teens with ADHD *(Gamino et al., 2009)*
  - Typical and disadvantaged middle schoolers in the classroom *(Gamino et al., 2010)*
  - Adults with brain injury *(Vas et al., 2011)*
  - Healthy adults *(Anand et al., 2011; Chapman et al., 2013)*
  - Adults with MCI *(Mudar et al., 2013)*

- Benefits also observed in academics, executive functions (inhibition, working memory, cognitive flexibility) and daily life functioning

Gist Reasoning Training in Adolescents with TBI

Issues addressed:

1. Does gist reasoning provide an index of complex cognitive stall in pediatric TBI?

2. Can gist reasoning serve as a platform to improve
   - Cognitive capacity – trained and untrained
   - Real life functionality

SMART: Strategic Memory & Reasoning Training

SMART:

- 8-10 on-on-one training sessions
- 45 minutes each
- Over a 4-week period
- Predominantly text-based materials, including the child’s own schoolwork

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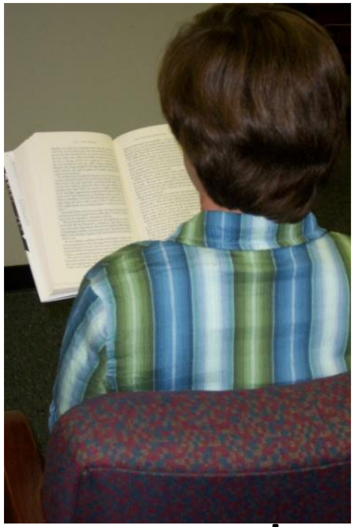
SMART Ideas

- Eliminate unimportant information
- Make inferences and uncover deeper meanings
- Put information in your own words
- Look for themes and summarize as you go
- Consider others’ perspectives
- Abstract multiple interpretations and “take-home” messages
- Zoom in and zoom out to show understanding of both the “forest” and the “trees”
- Come up with your own questions
- Apply new learning to create novel ideas



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Adolescent TBI Study 1: In-person SMART (*NICHD R21-HD062835*)

- 20 adolescents, ages 12-20 (M=15.30, SD=2.25), with complicated mild to severe TBI
- At least six months post-injury
- Randomized into either one-on-one SMART (gist-based training) or fact-based control training (rote memory strategies)
- Pre- and post-training assessments

(Cook et al., 2014, Frontiers in Neurology)

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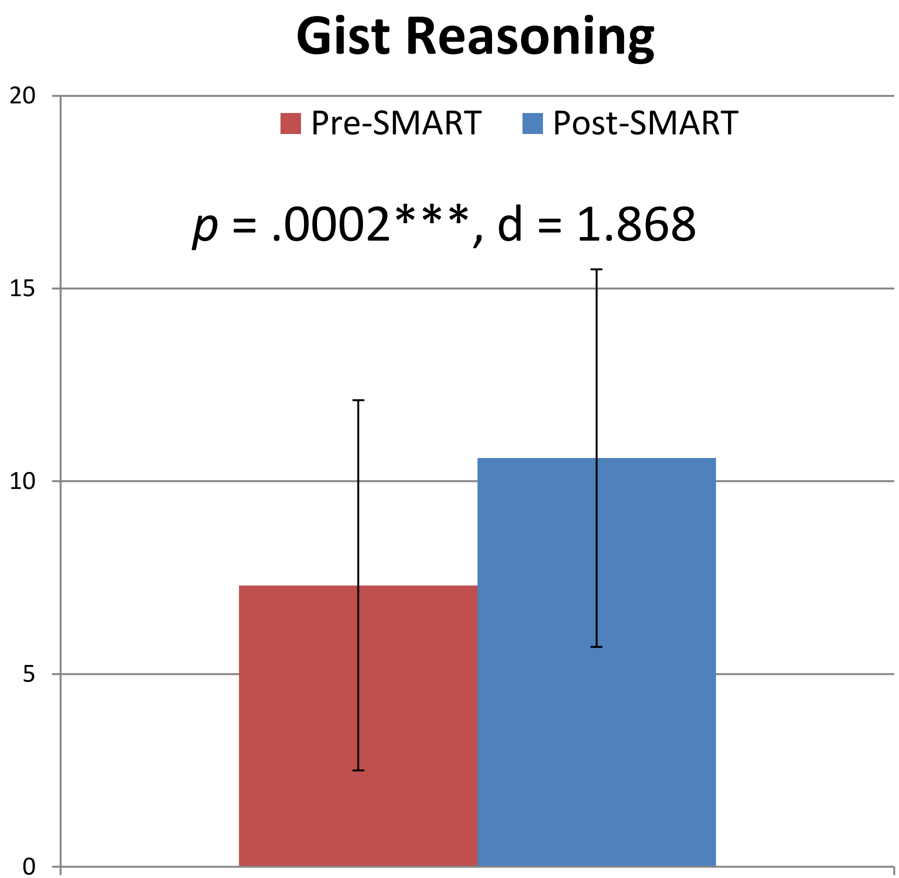
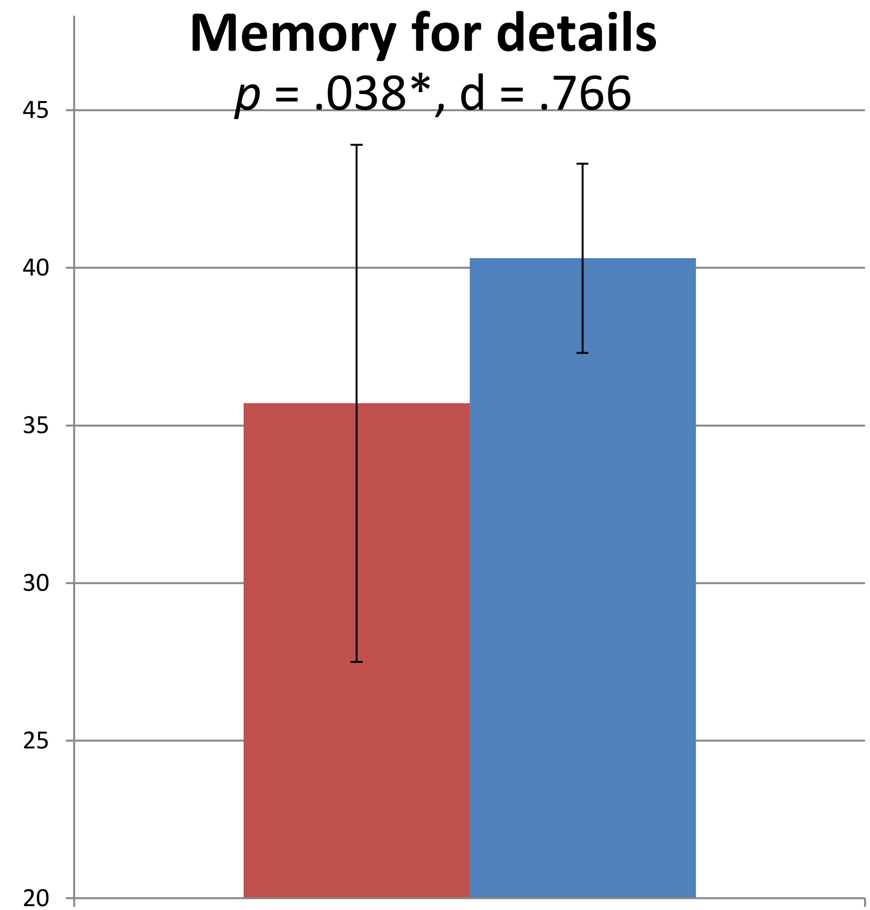
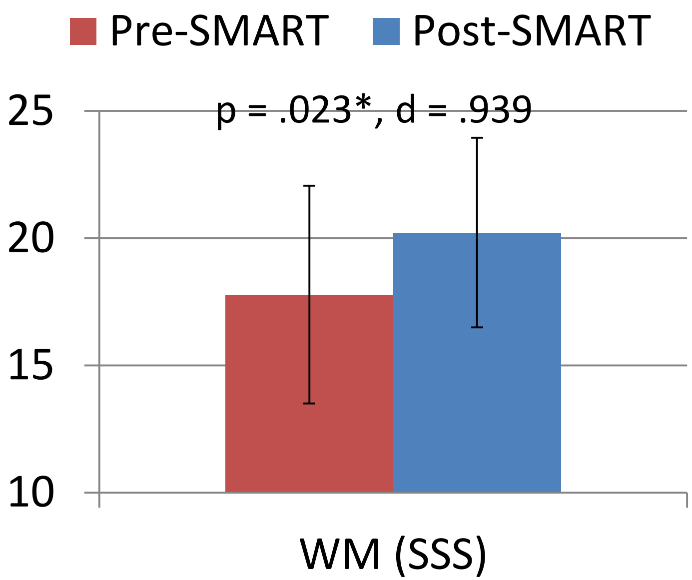
In-person Adolescent SMART: Primary Gains

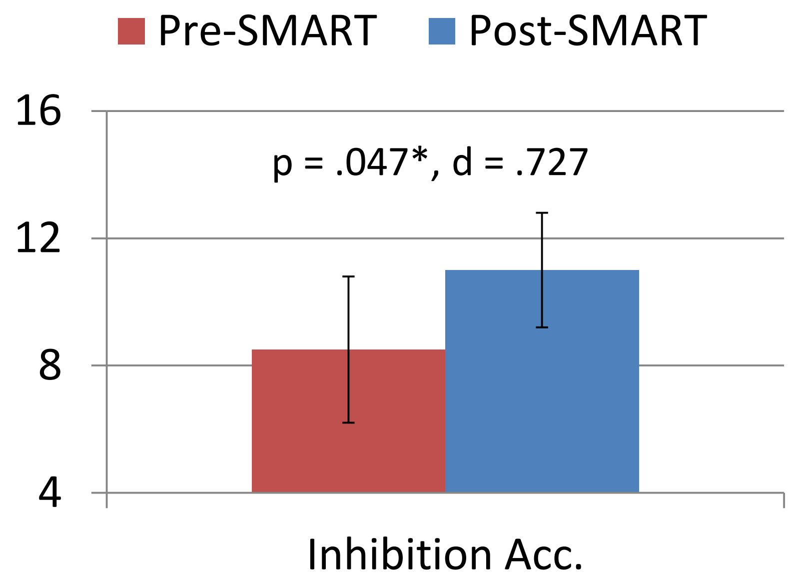


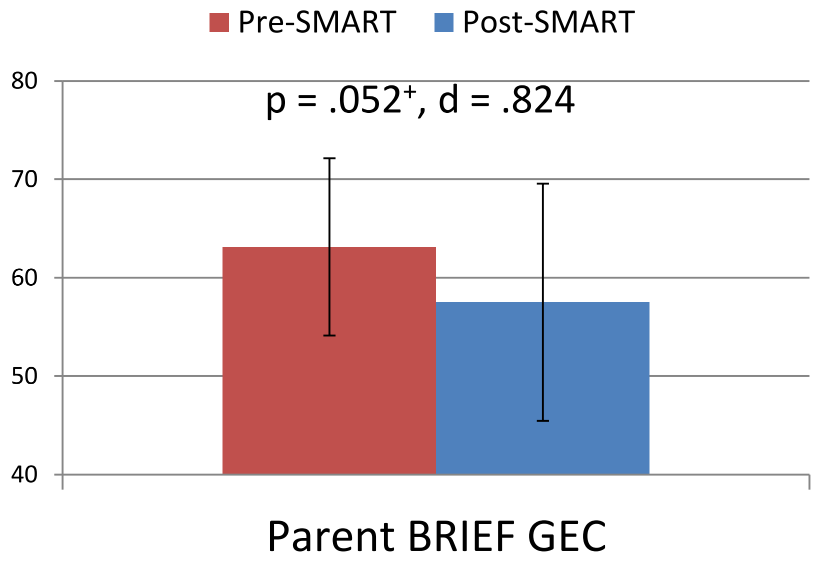


- In contrast, the Memory training yielded no significant gains
- The group difference (SMART vs. Memory) in effect of training on gist reasoning was significant (*p* = 0.006; *d* = 1.41)

In-person Adolescent SMART: Generalized Gains







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TBI Randomized Cognitive Training Trials
DOD & NIH funded

SMART gains compared to Active Control Group

Cognitive benefits (at 3 months after training)

23% increase *in* complex reasoning
38% increase in memory
14 % increase in daily life activities

Psychological Health (at 3 months after training)

58% decrease in depressive symptoms
42% decrease in stress-related symptoms

Enhanced neural health (cerebral blood flow)

Significant increase in CBF in SMART versus Control
Increased CBF linked to improved cognitive performance
Increased CBF in bilateral precuneus (emotional control)

Vas et al., 2015, Neuropsych. Rehab.

Virtual Reality Intervention

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Advantages of using Virtual Reality

- Practice of Real World Conversational Context
- Emotional Connection from the Participant
- Dynamic / Flexible
- Safe
- Recorded for Feedback

"We live in a highly social world that puts more emphasis on knowing somebody than work or brain power. The best thing about this program is that it's a very low-stakes way to practice interacting in everyday ways with others. It provides five to six years of social training in just a few sessions."

social cognition research participant

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Take-home messages

- A TBI typically affects frontal-mediated complex cognitive abilities
- A child with TBI can endure unique cognitive setbacks due to the vulnerable nature of the developing brain
- Significant impact on new learning, so long-term monitoring is crucial to avoid plateau of skills in later years/adolescence
- Assessment should characterize complex, integrated skills
- An integrative, strategy-based approach to rehabilitation can have a positive impact on overall cognitive performance and real-world functioning

- *Think strategically and think deeply. Any brain can benefit, young or old, whether in health, injury, or disease.*

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www.centerforbrainhealth.org
www.brainhealthdaily.com

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