Contemporary Model of Brain Functioning: Exploring the Evidence Base

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School Neuropsychology: The Key to Reconceptualizing Cognitive Processes for Cognitive Hypothesis Testing
Brain-derived neurotrophic factor (BDNF) has been found to be important in energy homeostasis in animal models, but little is known about its role in energy balance in humans. Heterozygous, variably sized, contiguous gene deletions causing haploinsufficiency of the WT1 and PAX6 genes on chromosome 11p13, approximately 4 Mb centromeric to BDNF (11p14.1), result in the Wilms' tumor, aniridia, genitourinary anomalies, and mental retardation (WAGR) syndrome. Hyperphagia and obesity were observed in a subgroup of patients with the WAGR syndrome. We hypothesized that the subphenotype of obesity in the WAGR syndrome is attributable to deletions that induce haploinsufficiency of BDNF.

Psychological Processes Tapped in Task

- Attention
- Phonological Coding
- Whole word recognition
- Reading fluency
- Processing speed
- Working memory
- Crystallized knowledge
- Receptive language
- Retrieval from long-term memory
- Monitoring, flexibility, and evaluation
- Emotional state (Emotional valence)
- Motivation and persistence

How could this relate to a struggling child in the classroom?
What types of evaluation tools could help a practitioner sort through the comprehension problem?
What instructional strategies could improve comprehension of this passage?
What Do We Know About Brain Maturation?

After all, our bodies grow at different rates — we reach puberty at different ages and our emotional maturity at different times as well. Why should our brains be any different?

Margaret Semrud-Clikeman, PhD, University of Minnesota

- Brain differentiation begins before birth and continues to develop throughout childhood
- Brain maturation throughout life, but most changes are in first 5 years, with frontal lobes last to completely develop
- Brain does not mature at same rate in each individual
- Brain functions do not mature at the same rate
- White and gray matter change significantly throughout childhood, adolescence, and adulthood
- Myelination (neural tracts), dendritic branching, and pruning continues throughout life
- More is not better, more efficient is better!
The NIH Study of Typical Brain Development

Deborah Waber, Ph.D - Children’s Hospital Boston and Harvard Medical School
Principles of Neurodevelopment: Classroom Learning and Behavioural Functioning

- Physiological development inextricably linked to environmental opportunity and exposure
- Many learning and psychological disorders have neurodevelopmental causes: Diathesis-Stress Model
- Plasticity allows for brain to rewire/compensate, adapting to both dysfunction and environment
- Plasticity works both ways, can increase functional pathways, but also dysfunctional ones if instructional mismatch
- Reciprocal Determinism: Cognition

Behavior

Environment
The Posterior-Anterior Axis
Luria’s Working Brain

• Three Principal Functional Units
  1. *Unit for Regulating Tone and Mental States*
     ▪ Structures: subcortical
  2. *Unit for Receiving, Analyzing, and Storing Information*
     ▪ Structures: posterior brain regions, occipital, temporal, parietal lobes
  3. *Unit for Programming, Regulation, and Verification of Mental Activity*
     ▪ Structures: frontal lobes; frontal-subcortical circuits
Luria’s Working Brain

- Three Laws of Functional Organization
  1. Hierarchical Organization
     - Primary – Clear brain-behavior relationships
     - Secondary – Integrative association cortex
     - Tertiary Cortex – Highest levels of cognition
  2. Diminishing Specificity
     - Primary – One function
     - Secondary – More than one function
     - Tertiary – Many functions, not specific
  3. Progressive Lateralization
     - Primary – LH/right side body; RH/left side body
     - Tertiary – LH/detail-learned; RH/global-novel
Lurian Interpretive Approach: The Working Brain

The Posterior-Anterior Axis
Unit for Receiving, Analyzing, and Storing Information
Visual Function:  
Dorsal and Ventral Streams

Dorsal “Where” Stream  
Spatial/Direction/Motion

V1

Superior Temporal Sulcus (STS) Stream

V2

Ventral “What” Stream  
Object/Form/Color

V2, V3, V5

V4

Ventral Stream

Dorsal Stream
The Posterior-Anterior Axis
Unit for Programming, Regulating, and Verifying Activity

The Brain Manager

Expressive Language

Association Motor

Primary Motor

Executive Functions

Internal Control

External Control

Working Memory, Memory Encoding & Retrieval (HERA)

Plan, Organize, Strategize, Monitor, Evaluate, Modify, & Change Behavior

Attention, Concentration, & Impulse Control
The Three Axes Interpretation:

The Posterior-Anterior Axis

**Anterior**
- Executive Functions
- Motor Output

**Posterior**
- Sensory Input
- Comprehension
# The Neuropsychology Pioneers: Early Models of Hemispheric Functions

<table>
<thead>
<tr>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading</td>
<td>Automatic</td>
</tr>
<tr>
<td>Major</td>
<td>Minor</td>
</tr>
<tr>
<td>Dominant</td>
<td>Nondominant</td>
</tr>
<tr>
<td>Verbal</td>
<td>Nonverbal</td>
</tr>
<tr>
<td>Analytic</td>
<td>Holistic</td>
</tr>
<tr>
<td>Sequential/Successive</td>
<td>Simultaneous</td>
</tr>
<tr>
<td>Local</td>
<td>Global</td>
</tr>
<tr>
<td>Routinized</td>
<td>Novel</td>
</tr>
</tbody>
</table>

Structural Hemispheric Differences

**Left Hemisphere**
- More Grey Matter
- More Primary Cortex
- More Intramodal Connections

**Right Hemisphere**
- More White Matter
- More Association Cortex
- More Intermodal Connections

Hemispheric Functions and Language
Explicit vs. Implicit Language

He stopped at the bank to make a deposit.

Question: What does bank mean?

Left Hemisphere → Explicit Language

He stopped at the bank because he had to stay dry.

Question: What does bank mean?

Right Hemisphere → Implicit Language
<table>
<thead>
<tr>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Demand</td>
<td>High Demand</td>
<td>Belger &amp; Banich, 1998</td>
</tr>
<tr>
<td>Fine Processes</td>
<td>Coarse Processes</td>
<td>Beeman/Chiarello, 1998</td>
</tr>
<tr>
<td>Close Semantic</td>
<td>Distant Semantic</td>
<td>Chiarello, 1998</td>
</tr>
<tr>
<td>Simple Syntax</td>
<td>Complex Syntax</td>
<td>Cooke et al., 2001</td>
</tr>
<tr>
<td>Concordant/Convergent</td>
<td>Discordant/Divergent</td>
<td>Bryan &amp; Hale, 2001</td>
</tr>
</tbody>
</table>
Language Brain Activation Patterns
(Glasser & Rilling, 2008)

**Left**
- Alphabetic principle
- Fluency
- Temporal
- Phonological Processing
- Explicit Language
- Speech (Articulation)
- Explicit comprehension

**Right**
- Rate
- Pitch
- Spectral
- Complex Language
- Implicit Language
- Multiple word meanings
- Speech (Prosody)
- Implicit comprehension
Hemispheric Differences in Visual Processes (Delis, Robertson, & Efron, 1986)

**Stimulus**

N
N
N
N
N
N
N
N

**Response**

Left Hemisphere Damage

Right Hemisphere Damage
Hemispheric Functions and Visual Skills

Face Recognition

Right Temporal Lobe ➔ Novel Images

Left Temporal Lobe ➔ Known Images
Where's The Evidence?

- Newborn language processing
- Musician processing of symphonies
- American Sign Language in the deaf
- Brain activation in novice-new learning vs. expert-learned
- Bilateral fMRI activation: Left and right for Verbal; Right and left for nonverbal processing

Psychological processes matter more than stimulus input or response output!

The Three Axes Interpretation: The Left-Right Dimension

Anterior
- Executive Functions
- Motor Output

Posterior
- Sensory Input
- Comprehension

Left Hemisphere
- Routinized/Detailed/Local
- Convergent/Concordant
- Crystallized Abilities

Right Hemisphere
- Novel/Global/Coarse
- Divergent/Discordant
- Fluid Abilities
The Third Axis: Regulating Brain Function

Inferior
- Executive Efficiency
- Precision in Motor and Language Action

Superior
- Executive Regulation and Supervision
Cortical-Subcortical Circuits: Executive Control

Does circuit impairment lead to emotional and behaviour disorders?

- Cortical: Cingulate, Motor, Oculo-motor, Dorsolateral Prefrontal, Orbital Prefrontal, Basal Ganglia/Thalamus, Cerebellum
- Subcortical: Running, Drawing, Watching Things, Reading, Managing life, Completing Tasks, Writing, Controlling Own Emotions and Behaviour
The Three Axes Interpretation

**Left Hemisphere**
- Routinized/Detailed/Local
- Convergent/Concordant
- Crystallized Abilities

**Right Hemisphere**
- Novel/Global/Coarse
- Divergent/Discordant
- Fluid Abilities

**Posterior**
- Sensory Input
- Comprehension

**Anterior/Superior**
- Executive Regulation and Supervision
- Motor Output

**Inferior**
- Executive Efficiency
- Precision of action
Jack and Jill went up the hill to go to the candy store. As they reached the store, Jack peered in the window. Jill said, “Come on, let’s go in.” She held the door open for Jack, and they both went inside. They said hello to Ms. Smith, the store clerk. They each picked out two pieces of candy, and paid Ms. Smith 10 cents for each piece. Jack said “Have a nice day Ms. Smith,” and they left the store together.

Comprehension Questions

1. Did Jack and Jill go down the hill to the store?
2. Who held the store door open?
3. What was the store clerk’s name?
4. How much did they pay for the candy?
5. What will they do next?
Linking Neuropsychological Assessment to Intervention: The Problem-Solving Continues
Tier 3
Comprehensive Evaluation for Special Education Determination and Service Delivery

The Cognitive Hypothesis Testing Model

1. Presenting Problem
2. Intellectual/Cognitive Problem
3. Administer/Score Intelligence Test
4. Interpret IQ or Demands Analysis
5. Cognitive Strengths/Weaknesses
6. Choose Related Construct Test
7. Administer/Score Related Construct Test
8. Interpret Constructs/Compare
9. Intervention Consultation
10. Choose Plausible Intervention
11. Collect Objective Intervention Data
12. Determine Intervention Efficacy
13. Continue/Terminate/Modify

Relevance of Brain Functioning in the Classroom
Get Them Engaged in Learning!

Functional Brain Organization and Anti-Correlated Systems

(Fox, Snyder, Vincent, Corbetta, Van Essen, & Raichle, 2005)

Task Positive Network
Externally Directed – Working on tasks

Task Negative Network
Internally Directed – Preoccupied – ‘zoned out’
## Recognizing Brain Functioning in the Classroom

<table>
<thead>
<tr>
<th>Brain Area</th>
<th>Possible Effects of Left Hemisphere Damage?</th>
<th>Possible Effects of Right Hemisphere Damage?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occipital Lobe</td>
<td>Slow reading, poor spelling with letter substitutions, difficulty with visual discrimination of details</td>
<td>Limited comprehension and writing when visual imagery required, object recognition limited</td>
</tr>
<tr>
<td>Dorsal Stream</td>
<td>Poor left/right orientation, sound-symbol association (i.e., alphabetic principle), and letter reversals</td>
<td>Poor handwriting and math from spatial deficits; poor awareness of self and environment during social</td>
</tr>
<tr>
<td>Ventral Stream</td>
<td>Difficulty recognizing sight words, poor reading fluency; object naming limited</td>
<td>Difficulty with sight words and perception of affect and faces</td>
</tr>
<tr>
<td>Lateral/Medial Temporal Lobe</td>
<td>Can’t remember facts and words due to difficulty with long-term memory, poor categorization</td>
<td>Limited understanding of context, metaphor, multiple word meanings, and humor</td>
</tr>
<tr>
<td>Superior Temporal Lobe</td>
<td>Frequent requests for repetition, poor word reading, poor auditory and phonological processing</td>
<td>Poor perception of rate and pitch or prosody, difficulty with complex sentence processing</td>
</tr>
<tr>
<td>Anterior Parietal Lobe</td>
<td>Poor right hand grasping, writing too light or dark, complains after writing that “hand hurts”</td>
<td>Poor left hand grasping and limited bimanual coordination skills</td>
</tr>
<tr>
<td>Brain Area</td>
<td>Possible Effects of Left Hemisphere Damage</td>
<td>Possible Effects of Right Hemisphere Damage</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Occipital-temporal-parietal crossroads and Wernicke’s Area</td>
<td>Difficulty connecting sounds (phonemes) with symbols (graphemes); difficulty connecting numbers with quantity and math algorithms, limited comprehension of explicit language</td>
<td>Poor math problem solving and comprehension of implicit language, complex language, poetry, difficulty with new learning and integrating different types of information; poor understanding of humor</td>
</tr>
<tr>
<td>Posterior Frontal Lobe</td>
<td>Difficulty with dressing, drawing, and handwriting; limited or no motor skill automaticity</td>
<td>Difficulty with learning new motor skills and sports requiring fine motor, difficulty with using both hand simultaneously</td>
</tr>
<tr>
<td>Broca’s Area</td>
<td>Halting speech with little output and difficulty with articulation and syntax, even impulse control</td>
<td>Poor verbal prosody and word substitutions; verbose, but limited pragmatics</td>
</tr>
<tr>
<td>Dorsolateral-Dorsal Cingulate</td>
<td>Poor encoding for storage, limited decision making, rigid and inflexible thinking, difficulty with concordant and convergent thought</td>
<td>Poor retrieval from long term memory, sustained attention, and novel problem solving; difficulty with discordant/divergent thought</td>
</tr>
<tr>
<td>Orbital-Ventral Cingulate</td>
<td>Depressive symptoms and avoidance/withdrawal, excessive emotional control</td>
<td>Disinhibition and indifference, aggression and or conduct problems</td>
</tr>
</tbody>
</table>
Implications for Differentiated Instruction: Neuropsychological Perspectives on Learning Stages

<table>
<thead>
<tr>
<th>GOAL</th>
<th>Accuracy</th>
<th>Fluency</th>
<th>Retention</th>
<th>Expansion</th>
<th>Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% to 25%</td>
<td>Acquisition</td>
<td>High Rate &amp; Accuracy</td>
<td>High Rate &amp; Accuracy</td>
<td>Transfer to Settings &amp; Responses</td>
<td>Capitalize On Knowledge And Skills</td>
</tr>
<tr>
<td>25% to 85%</td>
<td>Proficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0% to 25%</td>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Brain Activity: Frontal & LH RH

Frontal & LH

LH
Conclusions

- Educators and school psychologists need a better understanding of how the brain affects learning and behavior in the classroom.
- Early conceptualizations of brain-behavior relationships (e.g., verbal/nonverbal) have been replaced with modern conceptualizations and practices.
- Effective school neuropsychological interpretation focuses on psychological processes (i.e., idiographic interpretation), but tests hypotheses with additional measures to ensure accuracy.
- Differential diagnosis is only one component of comprehensive CHT evaluations; the real utility of the approach is guiding classroom interventions within the context of a problem-solving model to ensure ecological and treatment validity of findings.
- Understanding brain-behavior relationships during psychological testing and classroom instruction is the future of classroom education!
More Information:
Books by James B. Hale
THANK YOU!
QUESTIONS? COMMENTS?

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