Basic brain areas for word sense: Listening/speaking

Math is different

- = how many/how much
- = paying attention to the amount
- = talking/writing about math
Get your math brain together with your language brain!

Brain connections for math
Rykhlevska, Uddin, Kondos and Menon 2009

Gray matter locations and white matter connections are reduced in developmental dyscalculia.

Brain Development – age 5 to 20

Brain imaging P. M. Thompson, UCLA
Summary – brain development

- Brain areas from birth dedicated to quantity
- Brain structures that develop with experience
  - Visual number form area (VNFA)
  - Links to language
  - Connections for understanding concepts
- Both specialized areas and connections are reduced in Dyscalculia

Cognitive development in math:  
**Preschool**

- From birth: subitizing, estimating – the approximate number system
- Discriminate more/less
- Understand cardinality
- Learn counting words
- Associate word with specific quantity – the exact number system
- add and subtract one
- Use fingers/objects to aid adding
Cognitive Development in Math
*Age 5-7*

- Learn number symbols – the exact number system
- Add small numbers without counting out
  - $2 + 2 = 4$
- Shift in adding strategy $3 + 5 = ?$
  - Counting all 1,2,3,4,5,6,7,8
  - Counting on (min) 3...4,5,6,7,8
  - Counting on (max) 5...6,7,8
- Gradual shift from using fingers/objects to retrieval
- Understand ordinality - number sequence

Numeracy Screener predicts elementary math achievement

Daniel Ansari lab: [www.numercaycscreener.org](http://www.numercaycscreener.org)

Cognitive development in math
*after 2nd grade*

- FOUNDATION BUILDING: success depends on it
- Increased use of retrieval
- Inverse relationship of addition and subtraction
- Base-10 arithmetic, place value
- Multiplication, division
- Fractions
- Decoding word problems
Learning is embodied

Our brains can’t do much without sensory input.

HANDS AND GESTURE are important for developing math processing

- Transition from approximate to exact counting?
- Visual-spatial understanding.
- Reducing cognitive load.
- Learning from each others’ gestures.

Susan Goldin-Meadow Lab, University of Chicago

VISION: Our brains must learn to see.
We must tune our brains for letters and numbers.

Typical readers tune for printed symbols between K and 2nd grade.
Bad vision can result in faulty brain pathways - "amblyopia"

• "20/20" vision is not enough. It only means that each eye can read lines on an eye chart 20 feet away.

• COMPREHENSIVE EXAM NEEDED to test vision for reading and math
  - far and near visual acuity
  - binocular focusing
  - tracking coordination
  - eye health

6 months, 3 years, before first grade, every two years from age 6-18.

Solutions

• VISUAL ACUITY – Glasses.

• VISUAL FUNCTION – Vision therapy for binocular focusing, tracking, brain processing.
How Memory Works

- Perception (important!)
- Short-term memory
- Working memory (very small)
- Long-term memory (lots of space here!)

School curriculum/teaching

- Working memory is limited.
- Stored information is necessary.

37 x 45 = ?

- Place value: 37 is 3 tens, 7 ones
- x means multiply
- Multiply: repeated addition
- = same value both sides
- Procedure
- Facts: 5 x 7 = 35

Goal: Build automatic retrieval

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School curriculum/teaching

**goal: avoid cognitive overload**

What children need

- A solid foundation in long-term memory.
- Automatic access to stored information.
- Teaching that recognizes brain development and avoids cognitive overload:
  - multisensory, in context – concrete to abstract
  - sequential, incremental
  - prescriptive - to build foundation, fill gaps

MEMORIZATION?

**YES !**

- Number symbols
- Math facts
- Enough procedural knowledge to grow on
- Enough to play with/think about
DIRECT INSTRUCTION or CONSTRUCTIVISM?

• **Direct instruction is necessary.**
  – Children don’t have time to reconstruct the evolution of math knowledge.
  – Working memory must be conserved.
  – Accessible long-term memory must be developed.

AND – Games, projects, labs, and explorations with skilled guidance and corrective interaction make sense and build deeper understanding.

PROCEDURES or CONCEPTS?

*This is not a chicken or egg question*

Conceptual Understanding ↔ Procedural Skill

an iterative process

Johnson, Siegler and Wagner, 2001
Especially important for students with Learning Disabilities:
A specific prescription that is sequential, incremental, and multisensory

Indications of Math disability/dyscalculia

- Lack of one-to-one correspondence
- Continued use of counting-all instead of counting on.
  - after age six
- Continued reliance on actual finger counting
- Less ability to use retrieval-based processes, more errors in retrieval.
  - after age seven for basic addition/subtraction
- Less ability to hold and manipulate information in working memory.

Reasons for Math Difficulty not just dyscalculia....

- Developmental dyscalculia (~5%) – core deficits?
  - Reduced magnitude awareness
  - Reduced visual-spatial awareness
  - Links to dyslexia, reduced verbal connections
  - Resulting in lack of VNFA and brain connections
- Asynchronous brain development
  - Working memory
  - Executive function
  - Attention and processing issues
- Foundation gaps
- Math anxiety

I can't help it! My brain's not ready yet.
Math and Reading Disability, ages 8-15
Neuropsych test differences –

<table>
<thead>
<tr>
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<th>Math Disability</th>
<th>Reading Disability</th>
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<tr>
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<td>Processing Speed</td>
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<td>Rapid Naming</td>
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</table>

✓ = most important

Willcutt et al. 2013

Set Shifting – Wisconsin Card Sorting Test

What isn’t working?
Assessments Ed Therapists can use

• Early Math Readiness – observe counting, finger knowledge, strategies
• Screen processing issues, refer to specialists
• Ansari Lab: www.numeracyscreener.org (free)
Strategies for early math development

- Build approximate number system/number sense
- Counting games
- Board games
- Bedtime math
- Begin to build the exact number system.

The Approximate Number System (ANS)
Panamath testing/training

http://www.panamath.org/download.php
Strategies for school math difficulty

- Working memory – cognitive load down, automaticity up
- Processing speed – fewer tasks, more time, vision support
- Set shifting – identify problems in mixed sets; interleaving

- Phonemic awareness – help with reading, multi-step word problems
- Rapid naming – avoid timed tests (question vision)

VISION: VISUAL CROWDING

If it’s hard to read, it’s hard to do: processing fluency affects effort prediction and motivation.
Song and Schwarz, 2008
Fewer errors and faster reading when letters and lines have wider spacing

Children ages 8-14, diagnosed dyslexic

Set shifting

<table>
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</tbody>
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Math difficulty and word problems

Cameron bought twelve pounds of candy corn for 79 cents a pound, and eighteen pounds of M&Ms for $1.09 a pound, planning to make packages of candy for the Northgate-Eastside game. The two types of candy will be mixed and sold in one-pound bags. What is the least price that Cameron can charge for each of the thirty bags, in order to make at least a 25% profit?

- Type-face, size, and spacing

   Challenge for visual processing and decoding
Math difficulty and word problems

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- Type-face, size, and spacing
- Alpha-numeric and place value language shifts
- Irrelevant details
- Multi-step, multiple processes

Challenges for visual processing, decoding, rule-shifting, inhibition, planning, working memory, and processing speed

Word problems – analyze and solve

- In track last week, the boys ran sixteen laps. The girls ran four more laps. Each lap is \( \frac{1}{4} \) mile. How many miles did the girls run?

- In track last week, the boys ran sixteen laps. The girls ran four more laps. Each lap is \( \frac{1}{4} \) mile. How many miles did the girls run? \[ 16 + 4 = 20 \times \frac{1}{4} = 5. \] The girls ran 5 miles.

Math anxiety

- Impact on Working Memory
- “Stereotype threat”
- Parent and teacher math anxiety.

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Students with good working memory ➔ potential to succeed in math

- High math anxiety: **CHOKE**
- Low math anxiety: **THRIVE**

Reframe anxiety as excitement

Mattarella-Micke A et al., 2011
Beilock lab

Strategies to relieve anxiety

- Parents — Model positive interaction with math.
  — Encourage support strategies. — Allow development.
- Students — Journal, get it off your chest.
  — Reappraise anxiety as excitement. — Get help.
- Teachers — Eliminate stereotype threat.
  — Use accommodations that reduce stress.
- Schools — Choose/train teacher role models.
  — Monitor achievement. — Work with parents.
Can we get there?

[Image of two children looking at a map]

Educational Therapists: Remedies for math difficulties

- Diagnose the issues — true dyscalculia, foundation gaps, development/curricula issues, anxiety.
- Be mindful of and refer out for processing issues — vision, hearing, attention.
- Design an individualized prescription for remediation and accommodation.
- Be professional in your work with the team — support teachers!

Selected references (see other links above)

- Behrend F et al., 2015. Math at home adds up to achievement at school. Science, 350(6257) 296-298

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