MAPPING THE MATH BRAIN

MATH PD 02-04-2020
PRESENTATION SEGMENT BY:
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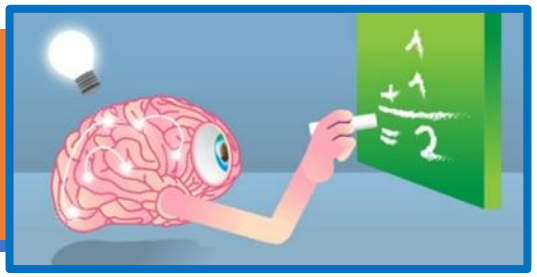

GOALS OF THIS SEGMENT - "Mapping the Math Brain":

- Introduce a brain-based educational model of math by identifying three basic neural codes which format numbers in the brain.
- Explore the role of three primary neurocognitive processes, with respect to math problem solving ability.
- Provide summary of:
  - Neurological processes with associated math skills
  - Math implications related to cognitive processing challenges
  - Suggested interventions for:
    - low cognitive skills
    - elevated anxiety levels
    - lower working memory skills
    - poor visual-spatial skills
    - attention

Information acquired from Feifer (2019) and Taylor (2018) workshop presentations.

Mapping the Math Brain

Common Myths:

- Math abilities are a by-product of intelligence
- Math is a right hemispheric task
  - *Language is in the Left Hemisphere*
  - *Math is in the Right Hemisphere*
- Boys outperform girls in math
- Math is independent of language

Skills needed for math:

1. **Working memory skills**
2. **Executive functioning skills**
3. **Language and verbal retrieval skills**
4. **Visual-spatial skills**

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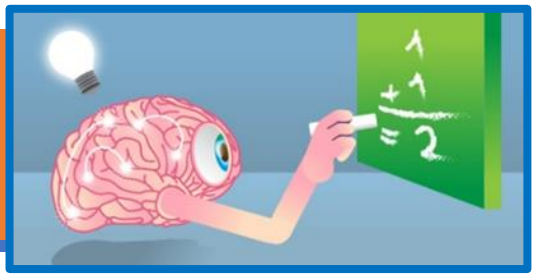

4 COMMON MYTHS ASSOCIATED WITH MATH

1. Math abilities are a by-product of IQ:
    a. Numerical abilities are evident in most animals, including quantitative knowledge. Studies show that primates, parrots, pigeons, and raccoons can subitize, estimate numbers, and perform simple addition and subtraction (Lakoff & Nunez, 2000).
    b. Numerical abilities in babies include the ability to discriminate up to four objects within the first week of life (Antell & Keating, 1983). Most three-day old newborns can also discriminate sound cadences of two and three syllables (Bijeljac-Babic, Bertoncini, & Mehler, 1991).
    c. "Savant" skills are defined by an uncanny mathematical ability in the presence of low cognitive skills. An overwhelming number are male, and one-third autistic (Anderson,1992) – Think of Dustin Hoffman's character in the movie *Rainman*. Calendrical calculations are among the most common such trait.
2. Math is a right hemispheric task:
    a. "Triple-Code Model" of mathematics suggest that multiple neural networks are involved in the processing of stored quantitative knowledge (Dahane & Cohen, 1997).
3. Boys outperform girls in math:
    a. No evidence at the elementary level, though some differences noted in high school and college (Hyde, Fennema, & Lamon, 1990).
    b. Males tend to be over-represented at both the high and low end of the distribution (Casey, Nuttall, & Pezaris, 1997).
    c. National Assessment of Educational Progress (NAEP, 2000) revealed gap between boys and girls evident only at high school, and has remained relatively small over the past ten years.
4. Math is independent of language:
    a. Verbal mechanisms vital for the retrieval of over-learned math facts such as multiplication tables and basic addition and subtraction facts.
    b. The language of math is critical to comprehending basic word problems (Levine & Reed, 1999).

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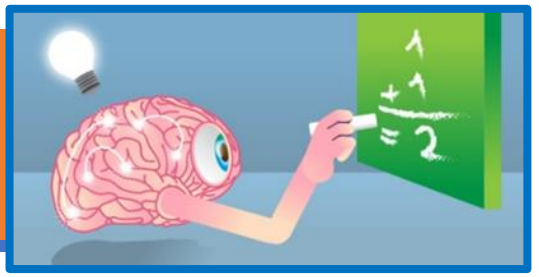
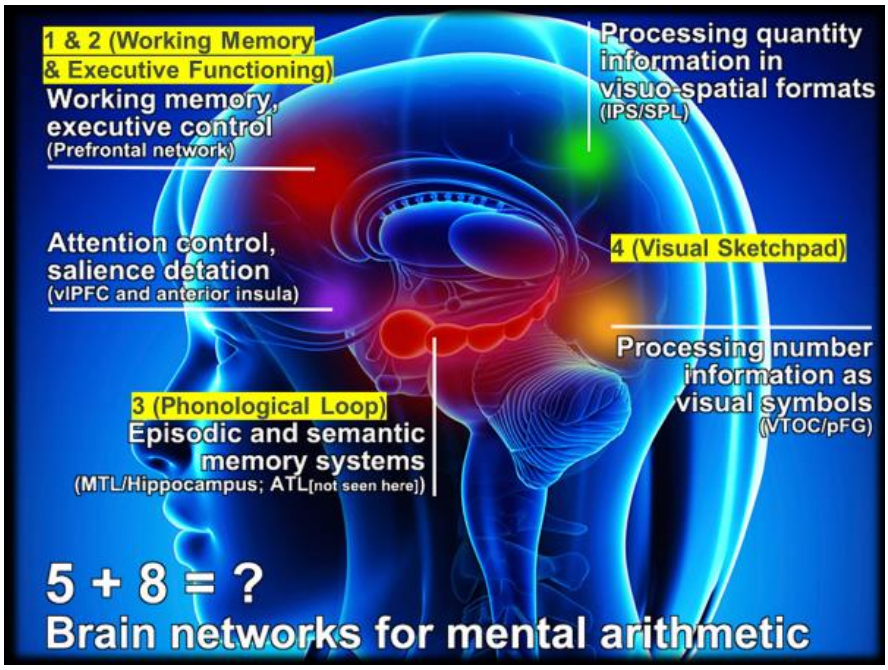


SKILLS NEEDED FOR MATH:

(Baddeley's (1998) Model)

1. Working memory skills
2. Executive functioning skills
3. Language and verbal retrieval skills
4. Visual-spatial skills



1. WORKING MEMORY SKILLS &
2. EXECUTIVE FUNCTIONING SKILLS

- Allocates cognitive resources to other memory systems.
- Fundamental in directing, shifting, and sustaining attention.
- Inhibits negative distracters
- Attention control

3. LANGUAGE AND VERBAL RETRIEVAL SKILLS: PHONOLOGICAL LOOP

- The mind's inner voice, refreshes information in the phonological storage
- Allows for verbal rehearsal of information
- Holds acoustical information for up to 2 seconds without rehearsal
- Capacity often associated with 7 +/-2
- Used for automatic retrieval of information stored in a verbal format
- Episodic and semantic memory systems

4. VISUAL-SPATIAL SKILLS: VISUAL-SPATIAL SKETCHPAD

- The mind's *inner eye*
- Visual imagery
- Mental rotation
- Facilitates mental math skills

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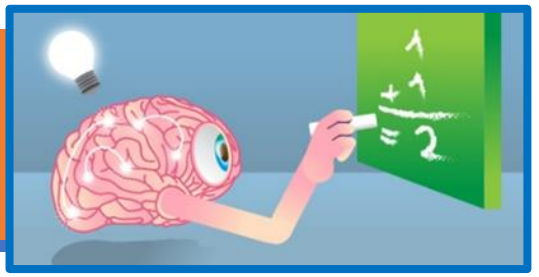

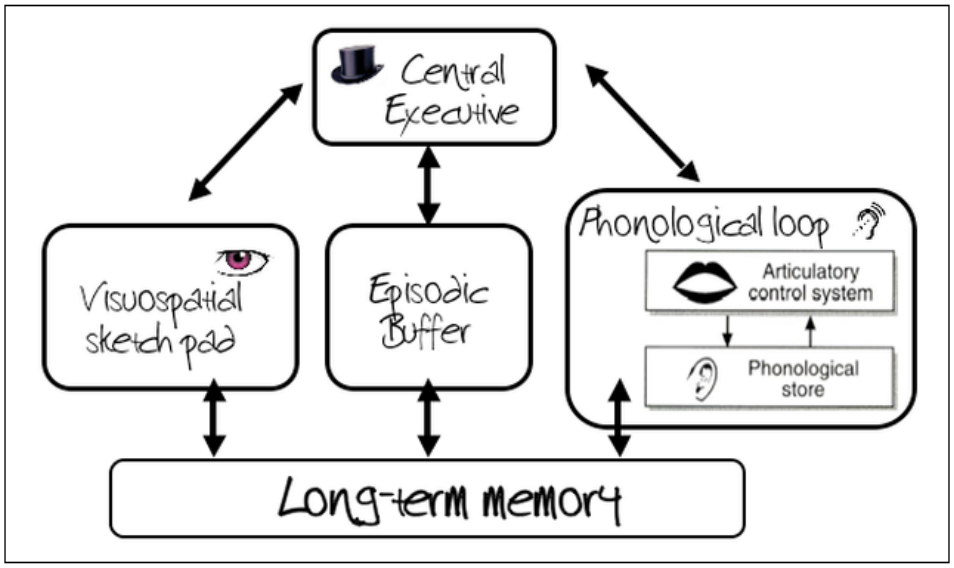

http://aspsychologyblackpoolsixth.weebly.com/working-memory-model.html

"The most important component is the **central executive**; it is involved in problem solving/decision-making. It also controls attention and plays a major role in planning and synthesizing information, not only from the subsidiary systems but also from long-term memory (LTM). It is flexible and can process information from any modality, although it does have a limited storage capacity and so can attend to a limited number if things at one time.

Another part of the working memory model is the **phonological loop**, it stores a limited number of speech-based sounds for brief periods. It is thought to consist of two components - the phonological store (inner ear) that allows acoustically coded items to be stored for a brief period and the articulatory control process (the inner voice) that allows sub-vocal repetition of the items stored in the phonological store.

Another important component is the **visuo-spatial scratch pad**; it stores visual and spatial information and can be thought of as an inner eye. It is responsible for setting up and manipulating mental images. Like the phonological loop, it has limited capacity but the limits of the two systems are independent. In other words, it is possible, for example, to rehearse a set of digits in the phonological loop while simultaneously making decisions about the spatial layout of a set of letters in the visual spatial scratchpad.

In 2000 Baddeley proposed an additional component, the **episodic buffer**. It is responsible for integrating & manipulating material; it has limited capacity and depends heavily on executive processing. It binds together information from different sources into chunks or episodes, hence the term 'episodic'. One of its important functions is to recall material from LTM & integrate it into short-term memory (STM) when working memory requires it (e.g. imagining an elephant ice-skating)."

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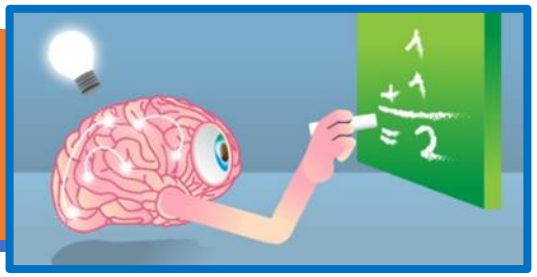
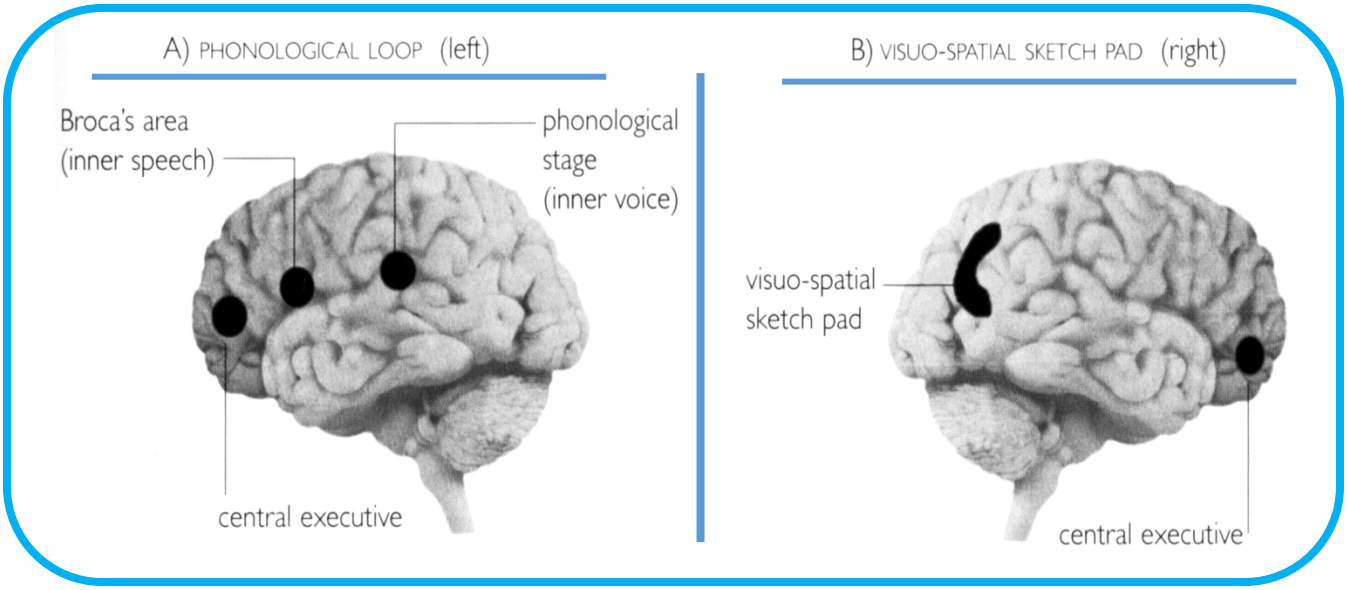


WORKING MEMORY AND MATHEMATICS



Working Memory System	Mathematical Skill
Central Executive System	▸ Transcoding mental operations ▸ Deciphering word problems ▸ Determining plausibility of results.
Phonological Loop	▸ Retrieval of math facts ▸ Reading numbers
Visual-Spatial Sketchpad	▸ Mental math ▸ Magnitude comparisons ▸ Geometric Proofs

MATH FLUENCY (Russell, 1999)

Efficiency: Student does not get bogged down into too many steps or lose track of logic or strategy. **(WORKING MEMORY)**

Accuracy: A working knowledge of number facts, combinations, and other important number relationships. **(AUTOMATIC RETRIEVAL)**

FLUENCY

Flexibility: Knowledge of more than one approach to problem solve. Allows student to choose appropriate strategy and to double check work. **(EXECUTIVE FUNCTIONING)**

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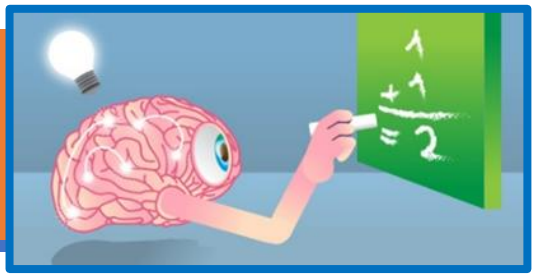
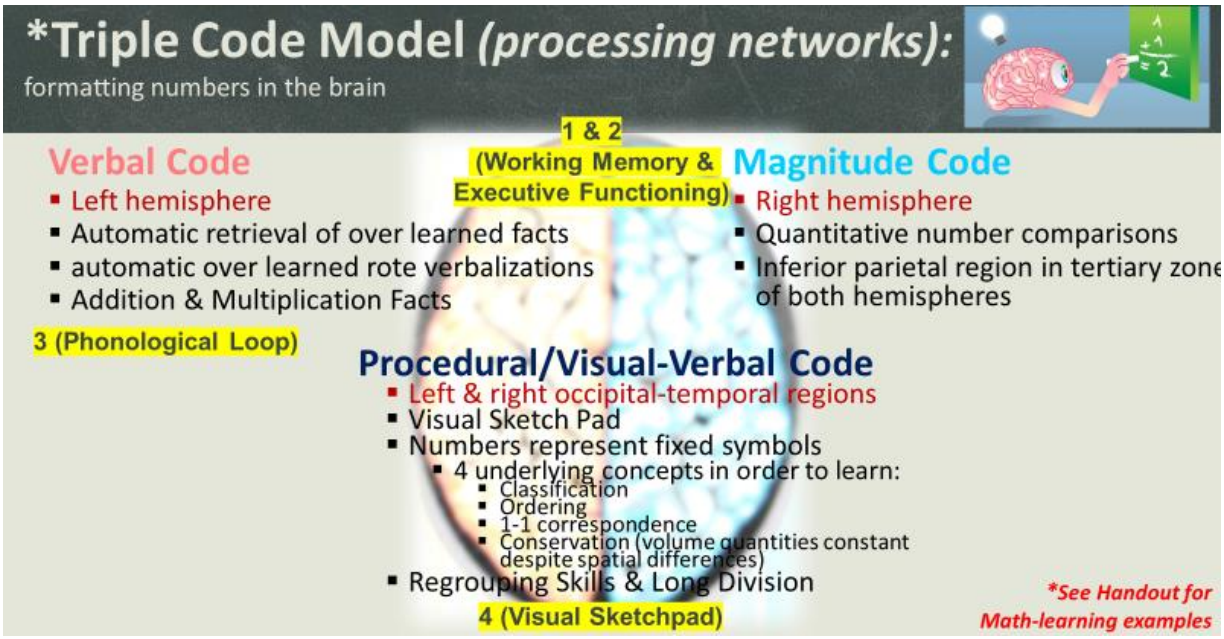


BRAIN-BASED EDUCATIONAL MODEL OF MATH

- 3 BASIC NEURAL CODES WHICH FORMAT NUMBERS



(1) ***Verbal Code:*** Numerals are encoded as sequences of words in a particular order (e.g. twenty-four instead of 24).

- Hence, a module exists where numbers are merely represented as number-words, primarily along the self-same brain regions which modulate most linguistic skills (Dehaene & Cohen, 1997).
- Specific deficits in this region can hinder the ability to name digits, and disrupt verbal memory of basic math facts (*i.e. nine time nine equals eighty-one).*
- According to Dehaene & Cohen (1997), mathematic operations such as rote addition facts and rote multiplication facts can most easily be transformed into a verbal code, and are often housed in this particular module.

(2) ***Procedural Code:*** (e.g. 1,2,3, instead of *one-two-three*).

- Here, numbers represent fixed symbols, instead of merely words, and this visual representation allows for the internal representation of a number value line (von Aster, 2000).
- According to Dehaene and Cohen (1997), mathematical properties and concepts can be represented in either a verbal code, or in a procedural code, though the interplay of both neural systems working together aids in the development of higher-level math abilities.

(3) ***Magnitude Code:*** refers to representations of analog quantities.

- Value judgements between two numerals, such as *9* is bigger than *3,* can be determined as well as estimation skills (Chocon, et. al., 1999).
- According to Dehaene and Cohen (1997), some research has suggested that both hemispheres become activated rather robustly during approximation tasks and when calculating large numbers, while the left hemisphere becomes activated only during recall of exact, over-learned mathematical facts (Stanescu-Cosson, 2000).

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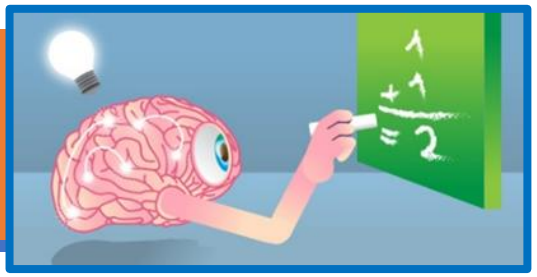
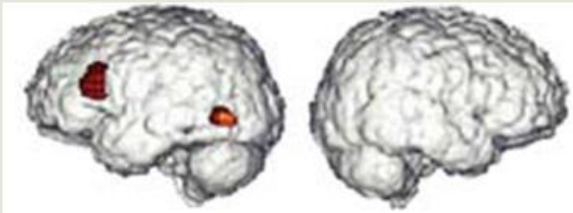
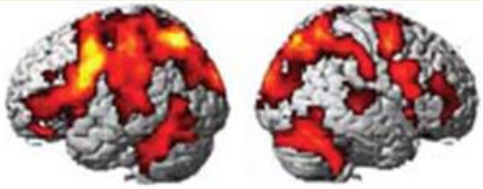


Doing Simple Math Fast is a Major Brain Stimulant

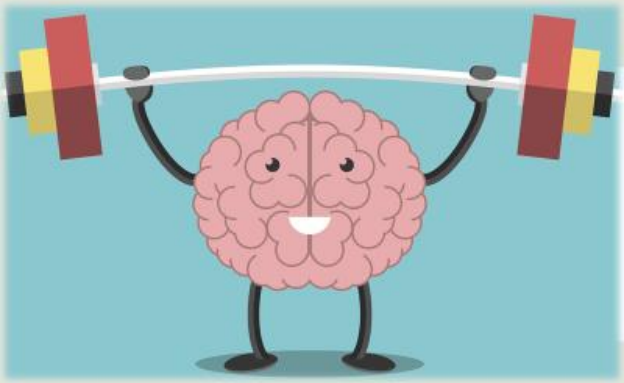


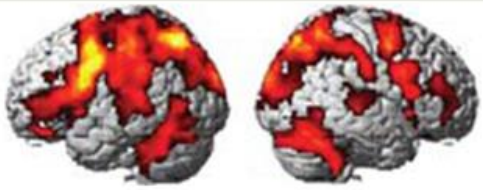
Working a Hard Math Problem



Working a Simple Math Problem Quickly

Doing Simple Math Fast is a Major Brain Stimulant





Working a Simple Math Problem Quickly

Activate!

Working Memory & Mathematics

(Feifer, 2019; Taylor, 2018)

Working Memory	Mathematical Skill
1a) Working Memory - Symbolic • Related to executive capacity of working memory • Each symbol (regardless of presentation format - auditory or visual) allows for *verbal rehearsal strategies* to keep information active through an inner articulatory loop while simultaneously resisting distractions	• Mental math calculation • Number line facility • Sequence of math steps (algorithm) • Facilitate math facts retrieval • Numeric pattern recognition skill • Cognitive representation of numbers • Facilitates algebraic problem solving
1b) Working Memory - Spatial • *Referred to as visual-spatial sketchpad of working memory* • Modulated by frontal & parietal lobe regions • A variable in the development of spatial & magnitude representation skills	• Alignment of numbers in columns • Magnitude comparisons • Estimation skills • Elapsed time • Verbal spatial problem solving • Facilitates geometric problem solving
2) Central Executive System • Central command post for modulating phonological loop & visual-spatial sketchpad systems • Allocates attention resources so multiple cognitive tasks can be executed	• Inhibits distractions • Modulates anxiety • Regulates emotional distress • Facilitates selective attention to math operational signs & key words in math word problems
3) Phonological Loop: • Storage of auditory & verbal information	• Write numbers from dictation • Take lecture notes in math class • Rapidly retrieve math facts stored in language dependent code • Help understand word problems
4) Visual-Spatial Sketchpad • Holds visual, spatial & kinesthetic information in temporary storage using mental imagery	• Mental Math Problem Solving • Helps line up place value when problem solving • Magnitude representation • Remembers sequence of steps or algorithm when problem solving • Aids in geometry • Facilitates solving proofs

Math Implications Related to Cognitive Processing Challenges

(Feifer, 2019; Taylor, 2018)

Area of Cognitive Challenge	Math Implication
Crystalized Knowledge	• Difficulty with word problems • Poor retrieval of over learned facts • Difficulty with math terminology
Visual-Spatial Processing	• Difficulty lining up equations/numbers • Poor magnitude comparisons • Geometry • Maps/Charts/Graphs
Nonverbal Fluid Reasoning	• Poor mental math skills • Difficulty with estimation skills • Poor pattern recognition skills • Poor strategy formation skills
Verbal Fluid Reasoning	• Difficulty w/ word problems • Limited inferential learning skills • Poor understanding of Math terminology
Memory	• Tendency to forget steps of an algorithm in multiple step math problems • Poor regrouping skills • Difficulty with mental rotation tasks • Poor mental math skills
Processing Speed	• Difficulty with speeded skill drills • Slower visual pattern recognition

Language/Math Delay Connections

Language Difficulties	Math Difficulties
Overall Language Development	Math disabilities
Pervasive problems in expressive and receptive language	Deficits in number reasoning & arithmetic problems
Expressive language only deficits	Delays with overall counting skills

Suggested Interventions (Taylor, 2018)

Low Cognitive Skills:

- Manipulatives and hands-on type of instruction.
- Number-line situated on student's desk.
- Drill and repetition.
- Focus on algorithm.
- Skip counting.
- Tap a drum beat when counting.
- Check for plausibility of response.
- Have student tell a number story to insure comprehension.
- Teach "math vocabulary"
- Utilize music, especially rap, to over-learn facts.
- Incorporate an area of passion in all lessons (e.g. sports statistics, etc.)

Elevated Anxiety Levels:

- Teach multiple ways to problem solve
- Avoid skill drills
  - Focus on strategy drills
- Link problem solving with personal interests/passion
- Set algorithmic procedures to a song
- Encourage visual cues

Poor Visual-Spatial Skills:

- Turn a visual problem into a verbal problem.
- Have students talk their way through a problem.
- Use graph paper to help line up equations.
- Make sure problems are written vertically as opposed to horizontally.
- Attach number-line to desk.

Greater emphasis teaching estimation skills and magnitude representations.

Lower Working Memory:

- Number-line situated on student's desk.
- Use a calculator.
- Reduce anxiety in the classroom.
- Increase number sense through games such as dice, domino's, cards, etc..
- Encourage paper and pencil use while calculating equations.

Use mnemonic techniques to teach math algorithm's and sequential steps

Attention:

- Circle math operation signs
- Write a small number above each step in the directions
- Write down all formulas before solving a problem
- Highlight, circle, or colour code math operational signs
- Talk aloud when problem solving
- Divide longer assignments into parts
- Double check work by tapping the eraser