



The Cognitive Effects of Threat and Anxiety on
Math Learning and Strategies for Remediation

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Universal Design for Learning

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Recognition Networks

The "what" of learning



How we gather facts and categorize what we see, hear, and read. Identifying letters, words, or an author's style are recognition tasks.

Strategic Networks

The "how" of learning



Planning and performing tasks. How we organize and express our ideas. Writing an essay or solving a math problem are strategic tasks.

Affective Networks

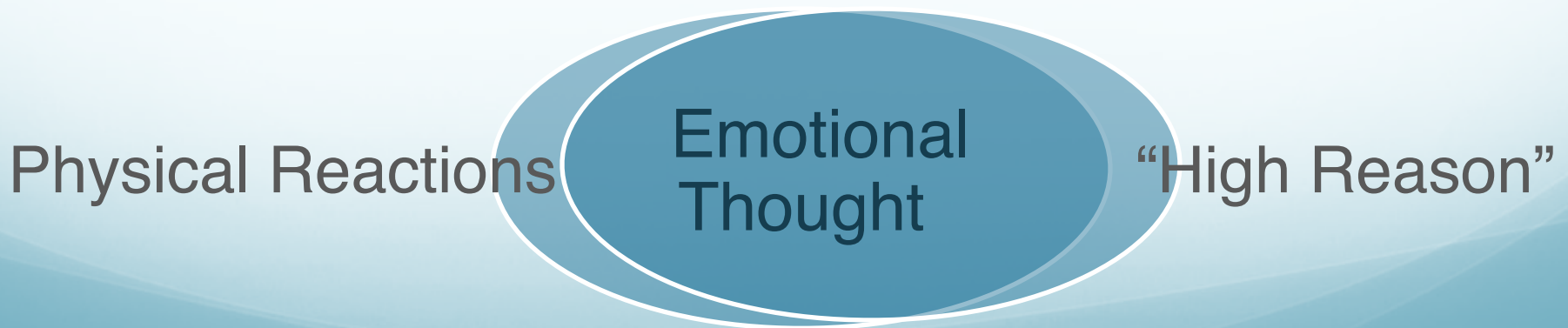
The "why" of learning



How learners get engaged and stay motivated. How they are challenged, excited, or interested. These are affective dimensions.

Research in Affective Neuroscience

- Learning, attention, memory, decision making, and social functioning are all controlled by emotion
- People whose emotional centers are damaged cannot make “rational” decisions



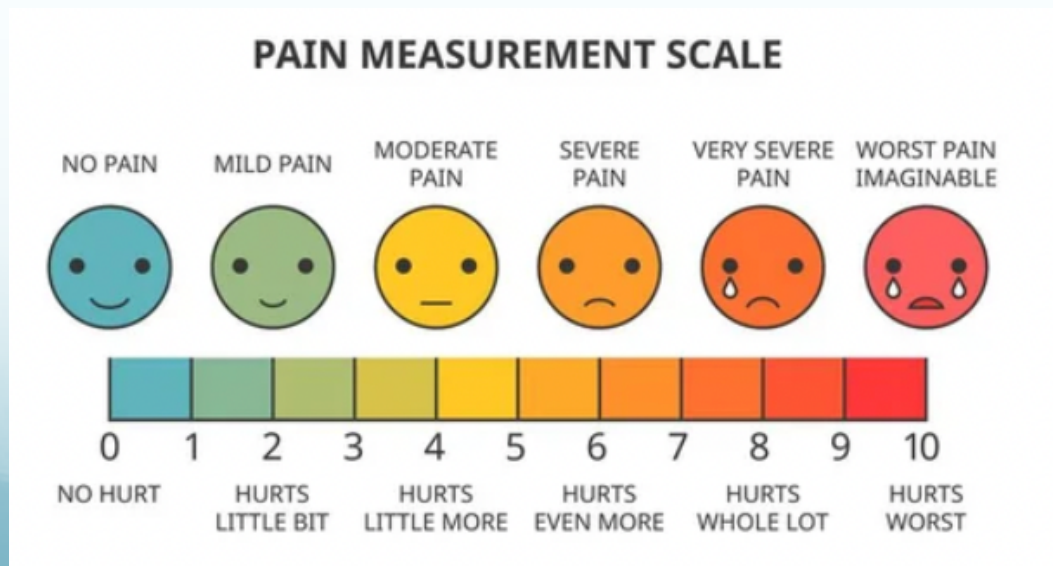
What is Math Anxiety?

- State anxiety (vs. trait anxiety) only present when doing math
- Different components of math anxiety:
 - Affective - emotional and physiological reaction to math
 - Cognitive - active worry while engaging in math work
 - Social/performance - board work in front of class, small group work with peers
 - Test anxiety
- Math Anxiety Rating Scales: MARS, sMARS, MAQ, and others. sMARS is trends toward the cognitive component, and MAQ towards affective

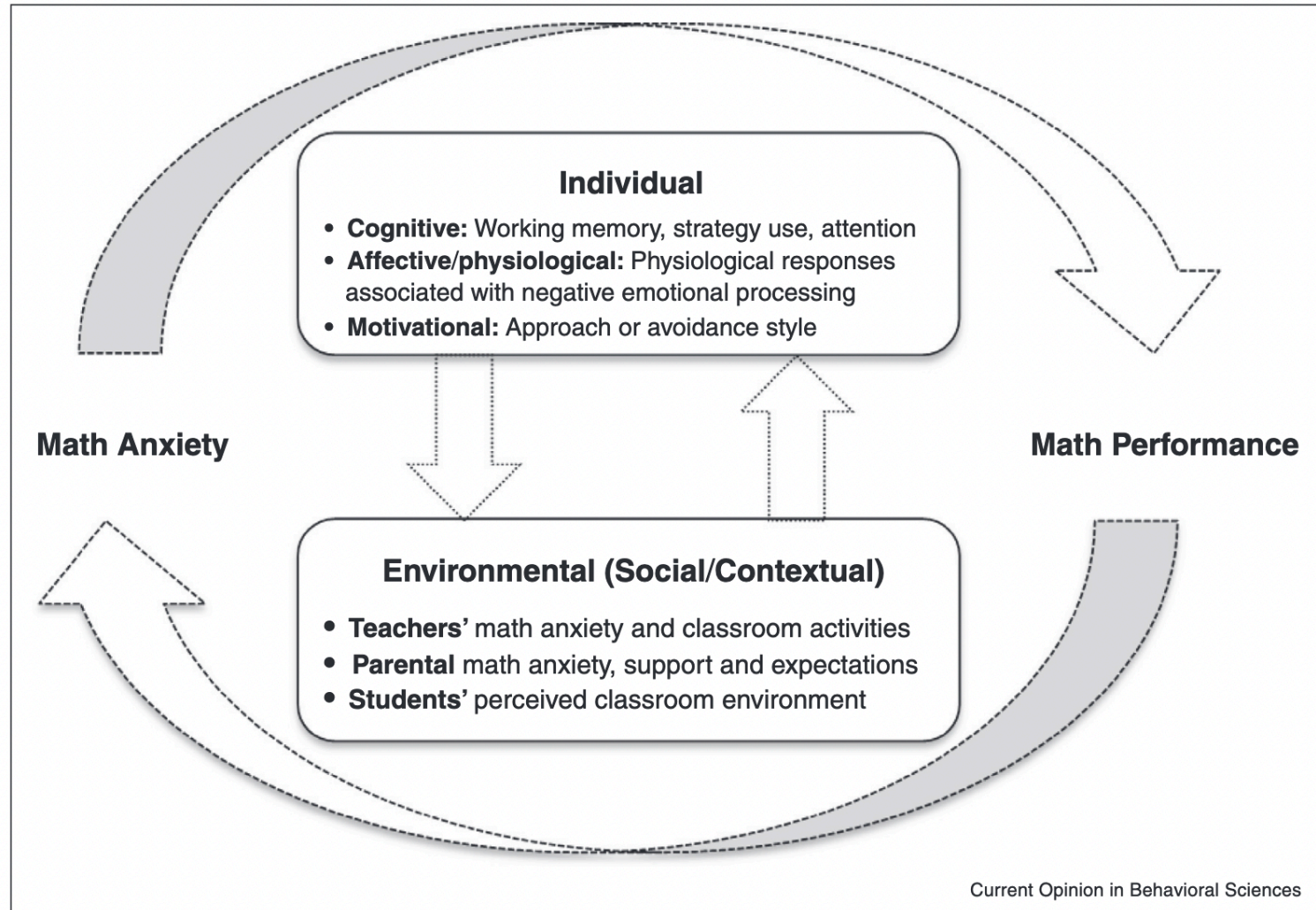


Quick and Easy Rating Scale

On a scale of 1-10, how math anxious are you?



The Performance/Anxiety Cycle



Prevalence

- 50% of elementary students suffer from math anxiety (Beilock and Willingham, 2014)
- 93% of American adults self-identify as being bad at or disliking math (Jackson and Leffingwell, 1999)
- In adolescence, we start to see a gender difference with girls self-reporting as more math anxious (Dowker et al, 2016)
- Grades 1-3 are more likely to present with stereotype threat (Beilock et al, 2010), with math anxiety arising in 4th/5th (Krinzinger et al, 2009)

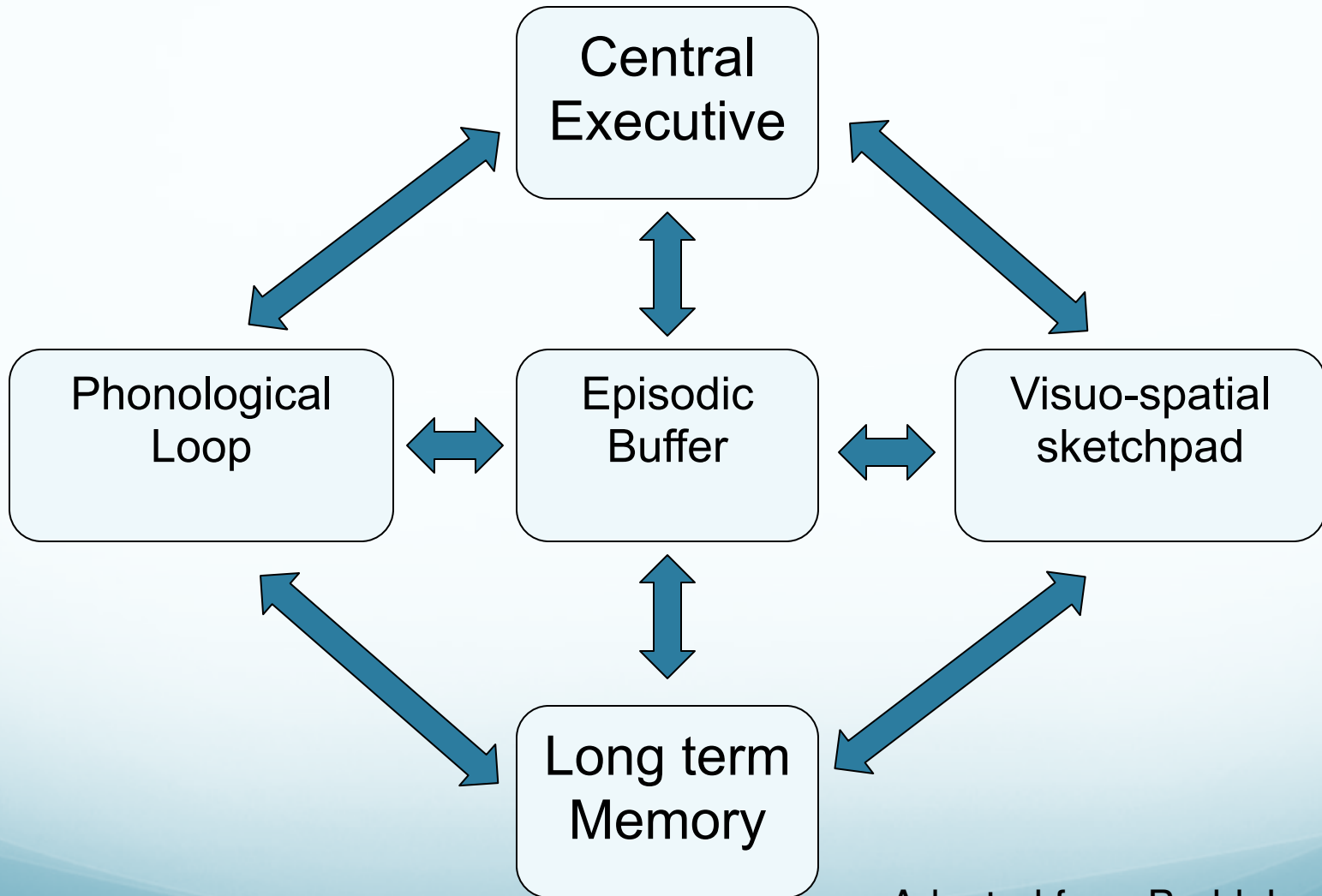
Anxiety vs. Threat

- Math Anxiety: Decreased performance stems from conscious worry over an expectation of high performance level
- Stereotype Threat: Decreased performance due to unconscious negative effects from an expectation of low performance level

Mirror Neurons and Math

- Both math anxiety and stereotype threat are largely due to modeled behavior by parents and teachers
 - Mirror neurons and emotional alignment
 - Body posture, eye movements, facial expression
 - Not attributable to math content
- Math anxious teachers spend less time preparing for math classes, less time teaching it
 - Teach skills instead of concepts
 - Model math avoidance

Working Memory



Adapted from Baddeley, 2010

Working Memory and Math

- Working memory is taxed by mental arithmetic: e.g., regrouping (or any task where manipulating numbers is required)
- Highly anxious people do worse on tasks that require working memory capacity
- Controlling for anxiety and taxing working memory reveals the same effect
- WM is NOT involved in rote memory tasks like retrieving simple math facts

(Ashcraft, 2002)

Working Memory

- Impaired/insufficient working memory can affect math performance without anxiety interference
- N-back task is widely used as a measure of working memory capacity and a method of improvement
- N-back can be auditory, visual, or spatial
- Multiple online options available:
 - <http://cognitivefun.net/test/4>
 - <https://www.brainurk.com/dual-n-back>
 - <https://www.psytoolkit.org/experiment-library/nback.html>

Neural correlates of Math Anxiety

- Decreased deactivation of the default mode network (DMN), involved in goal-directed behavior
- Increased activation of dorsal lateral prefrontal cortex (DLPFC), involved in attention and cognitive control
- Structural damage to the brain through reduced volume in the right amygdala, involved in fear processing
- Increased activation of dorso-posterior insula (INSp) and mid-cingulate cortex (MCC), the networks involved in the anticipation of physical pain

Default Mode Network (DMN)

Deactivation with high MA

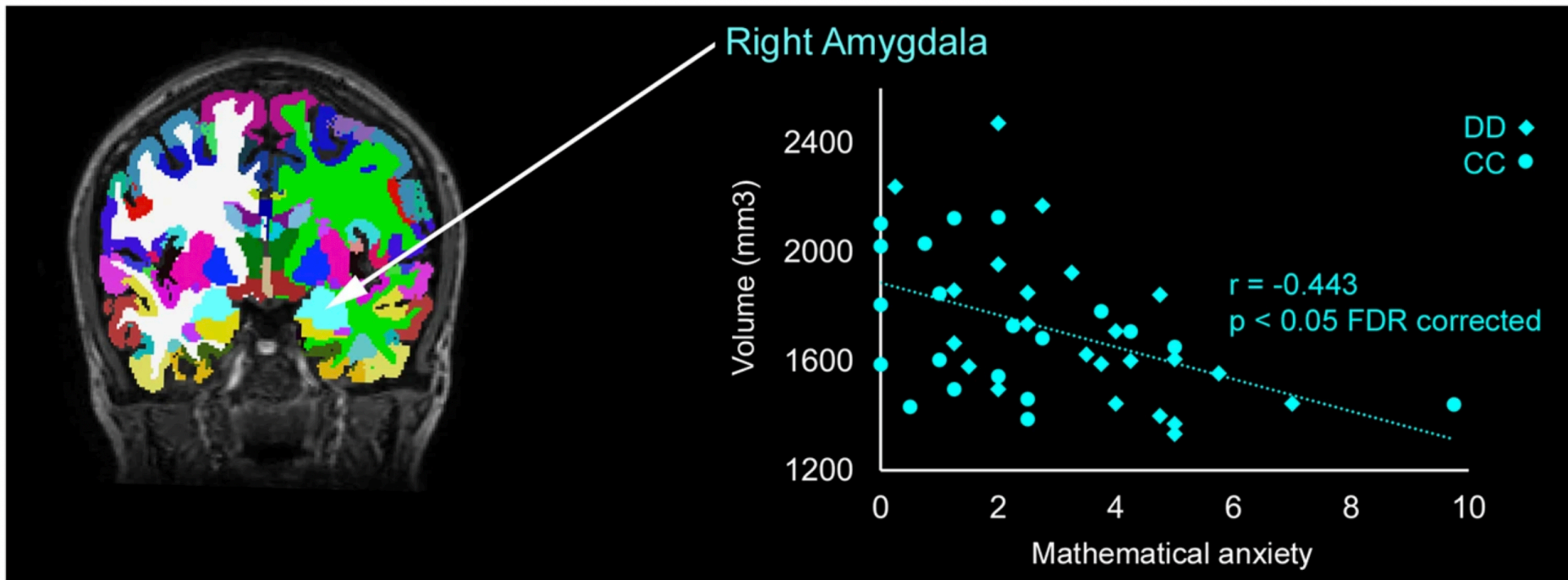
- DMN supports introspective social, self-referential, emotion processing. It's active in the resting state and deactivates during goal-directed behavior towards external stimuli (e.g., math). Deactivation = better processing efficiency.
- In HMA students, DMN is active, and goal-directed behavior and processing efficiency are impacted.
- DLPFC is also more active in HMA students, as they must devote cognitive resources (and working memory) to controlling their negative emotions, leading to decreased attention to the actual math

Processing Efficiency

- The cognitive aspect of math anxiety interferes with the phonological loop, but the affective aspect interferes with the central executive
- Decreased processing efficiency leads to difficulty with basic numeracy, such as place value
- Attentional control is also impacted
- Numeracy in the parietal lobes is NOT affected in HMA students, indicating that MA is NOT due to lower math ability

Reduced amygdala volume with increased math anxiety

From: [Neurostructural correlate of math anxiety in the brain of children](#)



Right amygdala volume is significantly smaller in children with developmental dyscalculia (DD, diamonds) and control children (CC, circles) with increasing math anxiety (0 = no math anxiety, 10 = very strong math anxiety)

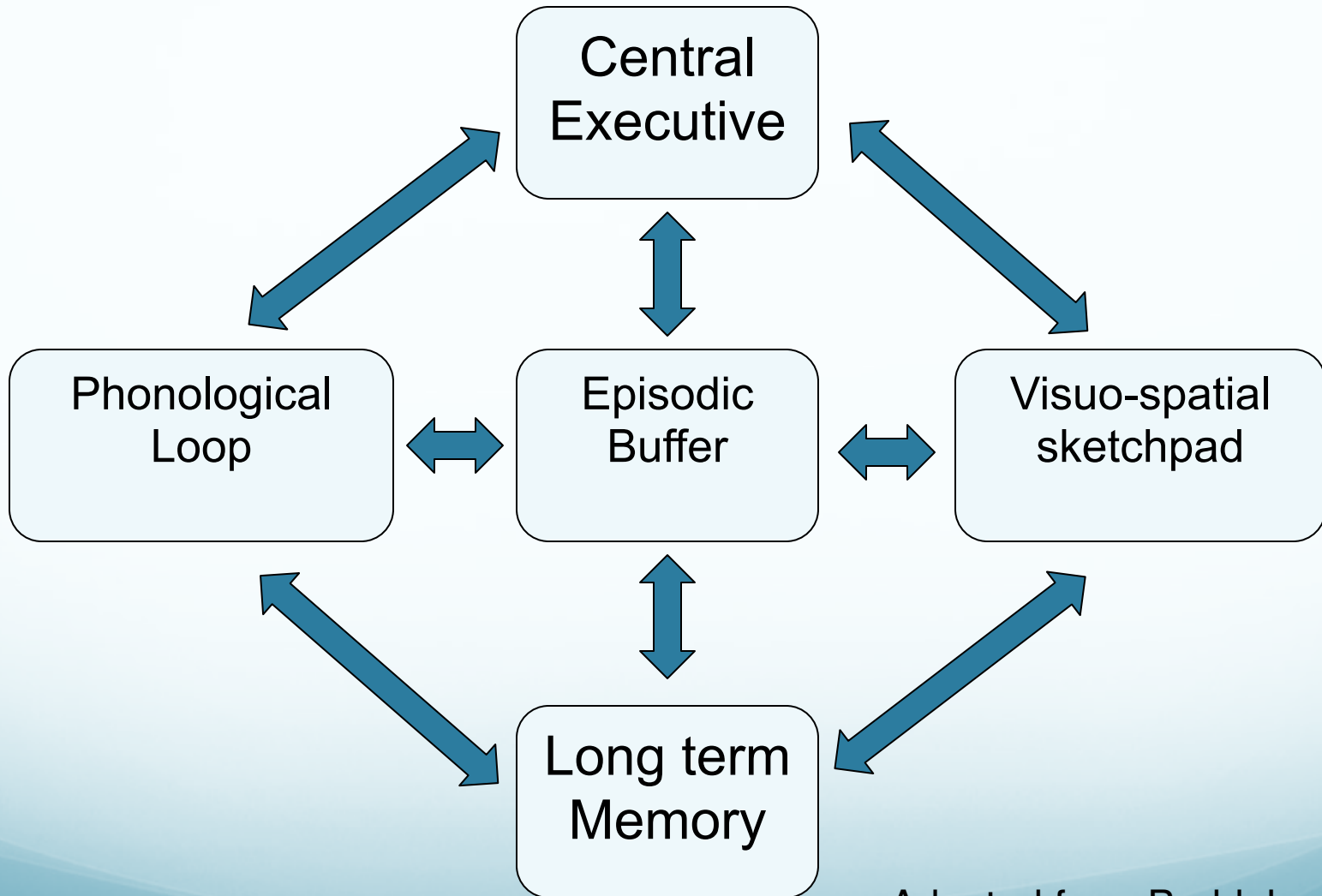
Covid Consequences

- Anxiety is omnipresent, for a variety of outside reasons, compounding the effects of math anxiety
- Absenteeism is soaring among teachers under more pressure than ever before, leaving untrained/ inexperienced teachers in charge
- Teachers under stress teach as they were taught, not using best practices
- Many students simply don't learn well online
- Parents a) are also under unprecedented levels of stress b) are not trained teachers and c) bring their own emotional history with math to the children

The Return of Algorithms

All these kids been learning Common Core math, bout to learn how to "Carry the One" from their new homeschool teachers.

Working Memory



Adapted from Baddeley, 2010

Why intervene?

- Children deserve to be math literate
 - Identity/emotional issues: “I’m not a math person”
 - Loss of job opportunities and deeper understanding
 - Generalizes to lifelong issues with financial literacy
- **Accountability** (Ashcraft & Moore, 2009): after anxiety onset in 4-5th grade, standardized tests are no longer an accurate measure of math ability
- Remediation of math anxiety is associated with over a twenty percentile point gain on standardized tests (Ma, 1999)

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What Works?

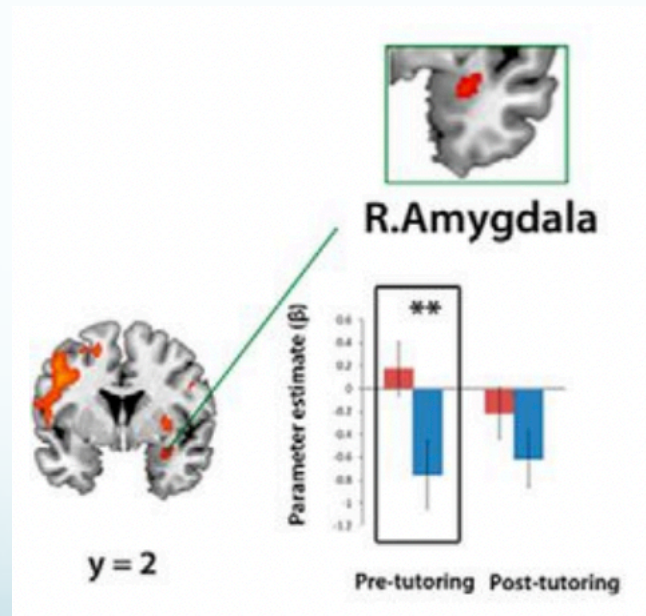
Research-proven interventions

(Chang and Beilock, 2016)

- Optimizing challenge to the individual - UDL
- Systematic desensitization
- Reappraising performance anxiety as excitement
- Focused breathing and mindfulness
- Relaxation training - PMR (Progressive Muscle Relaxation)
- Calming music
- CBT group therapy

Positive Effects of Educational Therapy

- 8 weeks of 1-1 cognitive tutoring remediated aberrant functional responses in the amygdala



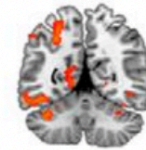
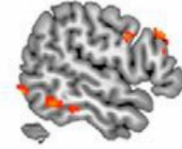
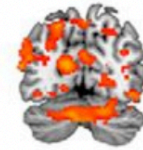
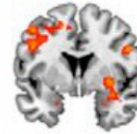
Putative Causes of Remediation

- Systematic desensitization
- Increased self-concept and confidence
- Opportunities for cognitive restructuring and other CBT techniques

Pre-tutoring: HMA vs. LMA

Amygdala

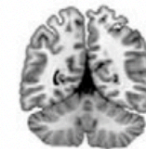
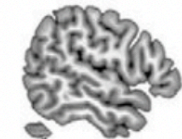
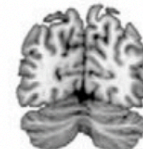
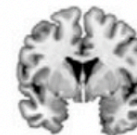
Fronto-parietal/VTOC



Post-tutoring: HMA vs. LMA

Amygdala

Fronto-parietal/VTOC



Prevention

All Grades

- Representation matters
 - Refer out to an ET of color whenever appropriate
- Optimize test-taking conditions
 - Remove race and gender identifiers
 - No clear majority in testing population
 - Tests to aid learning, not measure it
 - Reduce or eliminate timed testing
- Growth mindset language and mindful learning
 - Mindup Curriculum

Prevention

Pre-K – Grade 3

- Reduce math anxiety in teachers
 - Preservice teacher training – confidence and awareness
 - Mentoring and support from experienced teachers
- Minimize parent involvement in homework
- Teaching techniques for positive emotion
 - Storytelling
 - Schiro, M. (2004). *Oral Storytelling & Teaching Mathematics*. Thousand Oaks, CA: Sage Publications.
 - Zazkis, R. & Liljedahl, P. (2009). *Teaching Mathematics as Storytelling*. Rotterdam: Sense Publishers.
 - Games and Manipulatives
 - Kaye, P. (1987). *Games for Math*. New York: Pantheon Books
 - Number Worlds Curriculum, Infinut app, Dreambox app, etc

Math Activities and Games

- <https://gregtangmath.com/>
- <https://steveWyborne.com/>
- <https://berkeleyeverett.com/>
- <http://www.shodor.org/interactivate/activities/>
- <https://www.mathplayground.com/>
- <https://mathigon.org/activities>
- <https://deck.of.cards/>
- <https://www.nctm.org/Classroom-Resources/Illuminations/>
- <https://www.youcubed.org/resource/apps-games/>

In-person games/activities

- Race to 100 and other hundred board games
- Games for Math by Peggy Kaye
- Tiny Dots
- Savvy Subitizing (buildmathminds.com)
- Yahtzee and other dice games
- Pyramid and other card games
- Mathological Liar
- The 24 Game
- Equate
- Prime Climb

Online Manipulatives

- <https://app.brainingcamp.com/manipulatives>
- <https://www.mathlearningcenter.org/apps>
- <http://nlvm.usu.edu/en/nav/vlibrary.html>
- <https://mathsbot.com/#Manipulatives>
- <https://mathigon.org/polypad>
- <https://www.didax.com/math/virtual-manipulatives.html>
- <https://www.desmos.com/calculator>

Prevention and Intervention

Grades 4 – 12

- Games and Manipulatives are still important!
- Mindfulness training
- Start with traditional transmission style teaching before beginning more unfamiliar techniques
- Cognitive restructuring and growth mindset
 - Rephrase negative statements out loud
 - The power of YET
 - Support post-exam self-appraisals
 - Mistakes as positive opportunities

Prevention and Intervention

Grades 4 – 12

- Teachers as counselors and students as mentors
 - Be careful with consoling language!
- Convert anxiety from threat to challenge
 - “Harness the stress” to improve focus and concentration
 - Reappraise anxiety as excitement
- Reduce the threat level
 - Untimed or alternative assessments
 - “Imagine yourself as a white male” experiment
 - Power posing
- If ET is not enough, refer out for CBT
- Values Affirmation intervention for stereotype threat
 - Opportunity for collaboration!

What is Mindful Learning?

- Recognizing that school is stressful, and for many students, math in particular is a major stressor
- Explicitly teaching coping mechanisms for academic stressors
 - Lifelong skill for all subjects taught in context of a socially acceptable fear of math
 - SAT is another “in” for receptive students
- Not just math anxiety: mindfulness has been proven to be effective for ADHD (Mark Bertin)

Why Mindfulness?

- We are evolutionarily hardwired to run away from threats – if you don't run away from the lion, you're food!
- We cannot talk ourselves out of it – our prefrontal cortex shuts down so we don't lose running time thinking
- To calm our mind, we calm our bodies. This is part of mindfulness.
 - Square breath for ten seconds
 - In for 5, out for 7 (better with very young children)
- Once we are calm, we can look behind us and see there is no lion (functioning prefrontal cortex)
 - What do I know about the problem? Nobody knows everything, but everybody knows something.

Mirror Neurons

- Both math anxiety and stereotype threat are largely due to modeled behavior by parents and teachers
 - Mirror neurons and emotional alignment
 - Body posture, eye movements, facial expression
 - Not attributable to math content
- We can also model mindful behavior
 - Be the change that we want to see in our students
 - Build new pathways in the brain
 - Create mindful rituals around classes, test-taking

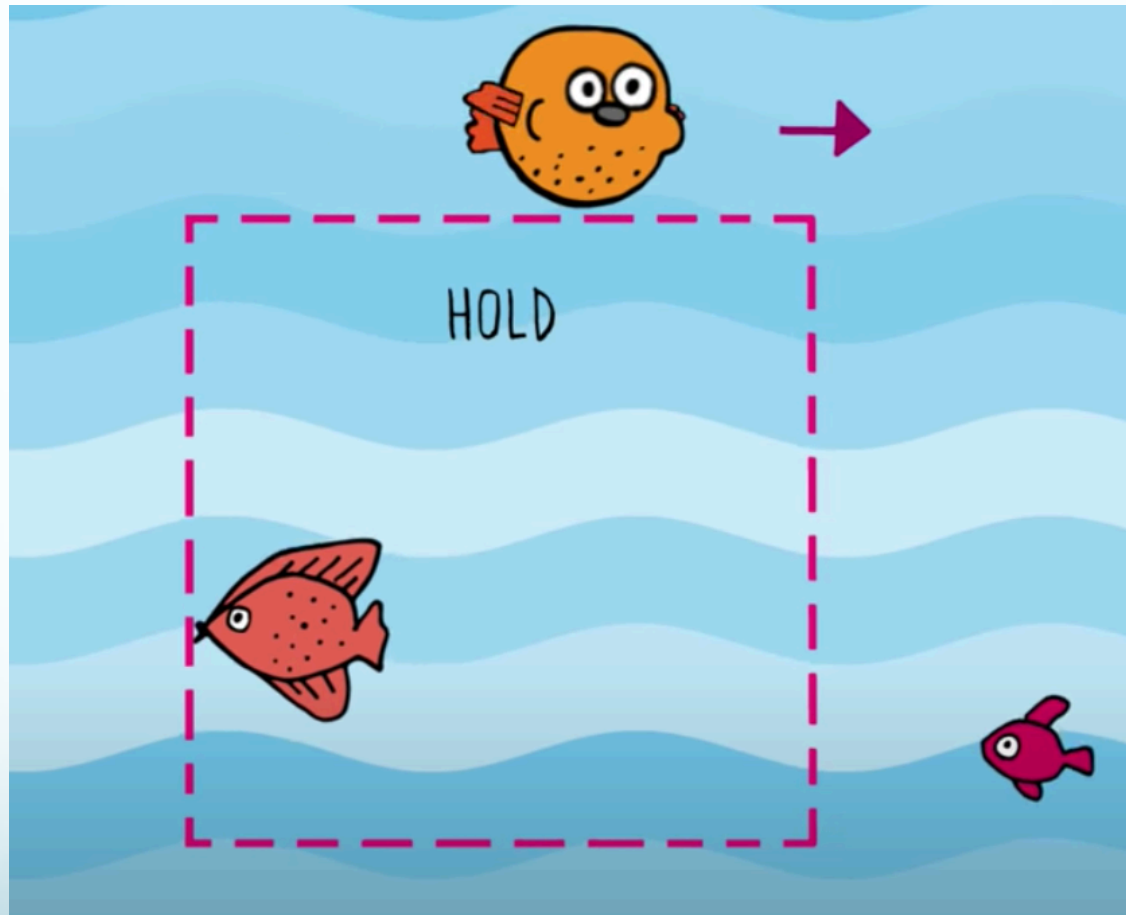
Mindful ET Practice in a Covid Era

- In-person Practice
 - How do masks affect us? How can we compensate?
 - Speak more clearly
 - Smile with your eyes
 - Communicate with your full body language
 - Students with NVLD will struggle, be more explicit in words
- Zoom Practice
 - “Zoom exhaustion”
 - Reading body language as a disembodied head
 - Time lag
 - Shared Google Docs for at-home practice with parent support

Mindful ET Practice

- Mindful rituals
 - Predictable, routine
 - Activate mirror neurons
 - Eye contact, (safe) handshakes
- Smiling
 - “Fake it till you make it”
 - Do not force it
- “Mindful Minute” guided meditation to start session
 - What do they hear? What do they feel in their bodies?
 - Mindful snack: What do they smell? What do they taste?
 - Count 10-15 mindful breaths with hands on stomach and chest
 - Can use a video for online practice

Square Breath



Mindful Video Resources

- <https://youtu.be/YFdZXwE6fRE>
 - Many free on youtube – place a dash before the U to get it without ads or autoplaying the next video
- <https://family.gonoodle.com/channels/flow>
 - Free, 3-4 minutes
- <https://gozen.com/allprograms/>
 - Paid program
- <https://ideas.classdojo.com/b/mindfulness>
 - Free

Mindful ET Practice

- “Chair Yoga”
 - Find your spine’s neutral position
 - Neck rolls, shoulder rolls
 - Seated cat/cow
 - Seated twist
 - Interlaced hands reach, wrist rolls
 - Self-massage of forearms, neck, base of skull
- Journaling (we’ll come back to this)
- Mindful Action – the “helper’s high”
 - Giving back to the community, being kind to someone else

Mindful ET Practice

- Paying attention is a skill that can be learned
 - Sustained attention, listening to a chime or gong
 - Who can listen the longest? Record times in journal and graph individual results over time (yay math!)
 - Doesn't work over zoom because of time lag
 - Directed attention, listening to sounds both inside and outside of the classroom, building
 - Builds executive function and particularly good for students with ADHD diagnoses or symptoms

Directed Attention

- Focus your mind on sounds in your own room
- Shift your focus to sounds in the building you are in
- Now see if you can hear anything from outside your building

- What did you hear?

STOP protocol

(Mark Bertin)

- **S**top what you're doing
- **T**ake a few breaths
- **O**bserve what's going on, internally and externally
- **P**roceed with intention, choosing what best to do next

Movement Breaks

- Dopamine allows us to focus and maintain attention
 - Depleted by sustained attention
- First 20-30 minutes: paying attention and learning. Next 20-30 minutes: focusing on trying to stay still (or getting in trouble for failing). Not learning.
- Start session with movement, then take a break half-way through
 - Ritual of movement breaks boosts dopamine levels
 - Choice of activity increases buy-in

Movement Breaks

- Jumping Jacks
- Hang a piece of yarn from the ceiling that's just out of reach. Have them jump to see if they can touch it.
- Stepping onto a block and back down
- Reach up to side on R, touch down to foot on L, repeat opposite side
- Running in place
- What do the students come up with?

Movement and Mindfulness

- Opportunity to focus inward once they're seated
 - Notice heart rate
 - Notice breathing
- Then, focus outward
 - What can you hear?
 - What can you see?
- Now you have a focused child with more dopamine
 - Directed attention exercises
- The ritual/repetition creates new pathways in the brain, allows for faster transition times

Journaling

- Practice Gratitude – write something every day that makes you grateful
- Record change over time to see change objectively
 - Changes can be in mood or achievement
- Twenty minutes once a semester to write out the values that make you uniquely you
 - Protects against stereotype threat, but only if they don't know what they're doing
- Write about a happy experience

Guided Processing

- Growth mindset language and the power of YET
- Cognitive restructuring around self-evaluation (especially after getting a test back)
 - Say it out loud!
- Recognize emotions and let them pass without judgment
 - Fear, anger, failure, jealousy, competitiveness
- Careful with consoling language – WARN PARENTS
 - Math is hard; I was never good at math either

The Role of Nature

- Time in nature has been shown to quiet the worried part of the brain (subgenual prefrontal cortex)
- Opportunity to spend time feeling and listening mindfully
 - “Homework” assignment = go outside for 20 mins
 - Journal about what you see, hear, feel, smell
- Beyond math anxiety, goals of mindfulness are becoming aware, slowing down the body, noticing common things in new light, finding joy, achieving goals, creating peace within oneself
 - Protection against all the other stressors we cannot control



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