

Brain, Body, and Learning: Insights from Neuroscience for Learning and Teaching



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THE UNIVERSITY OF ALABAMA®



Brain Awareness AUC Conference 2023

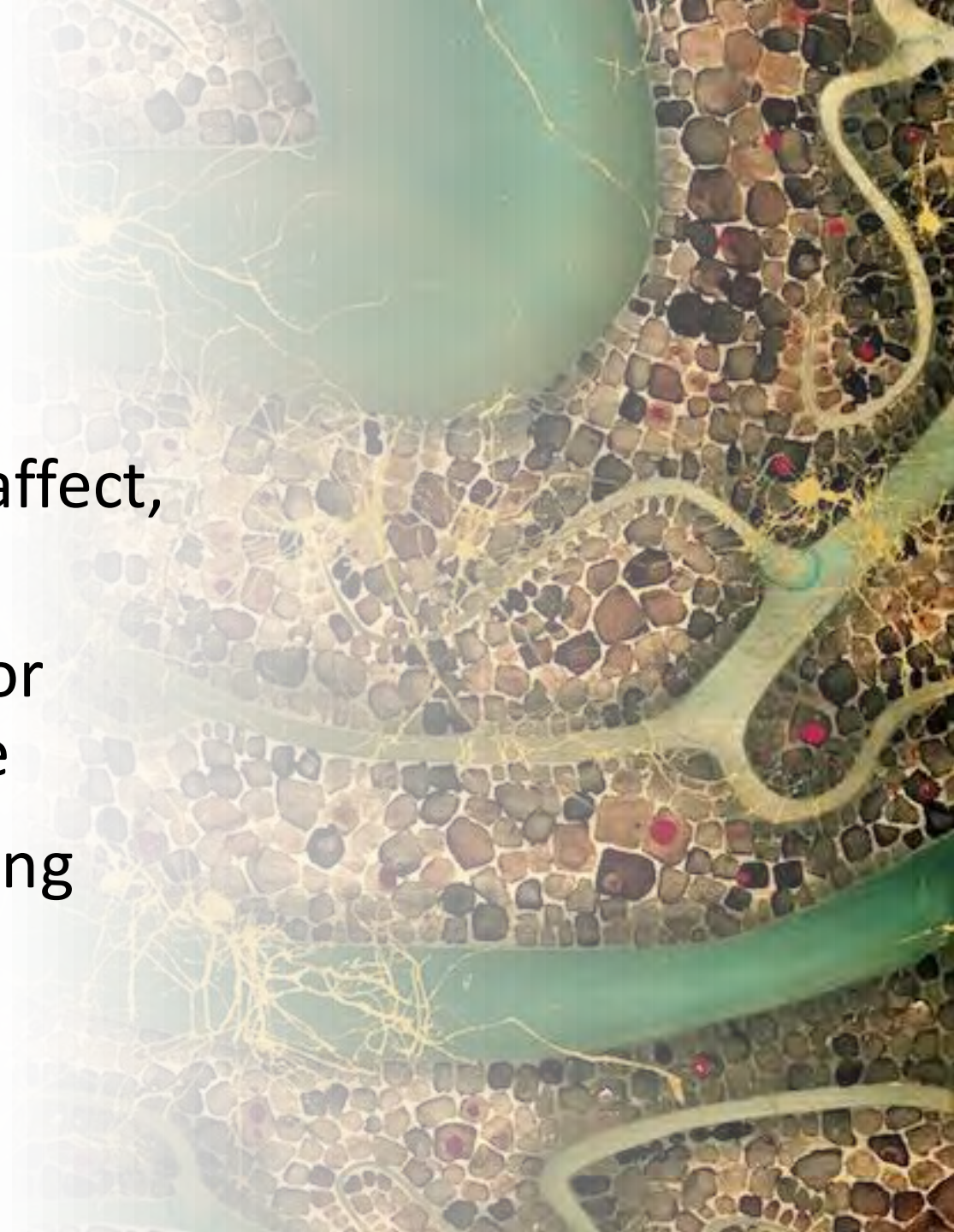
Outline

- Educational neuroscience
- Learning with our bodies
- Future of learning
- Discussion

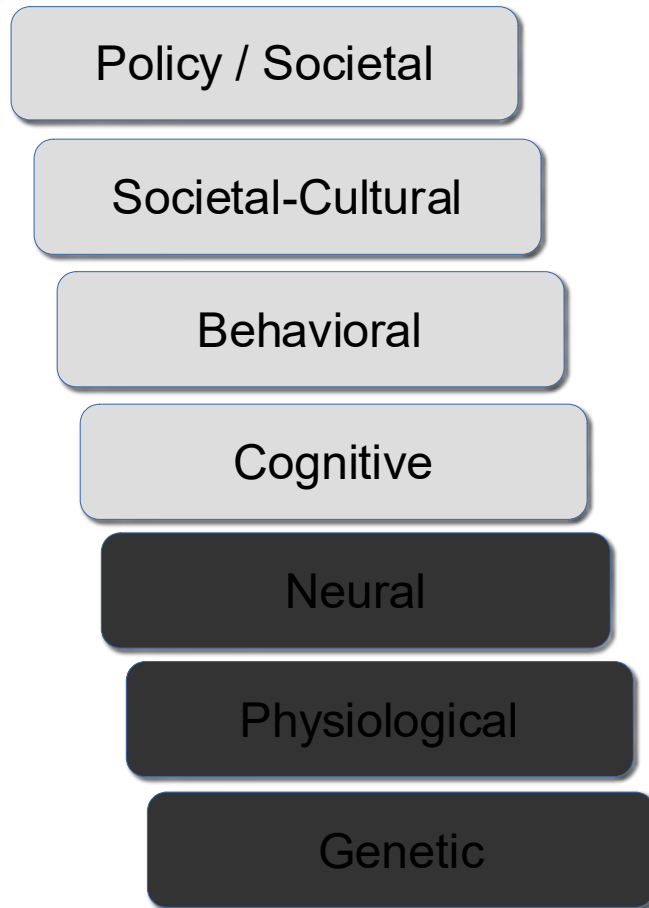


Educational Neuroscience

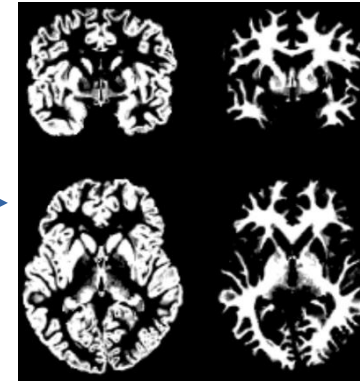
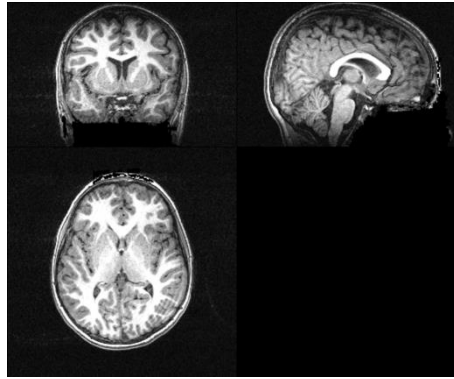
- Brain science relevant to education
- Biological explanations for learning, affect, motivation, and cognition
- Interpretation of empirical findings for learning design and teaching practice
- Increasing neuroscience literacy among students and teachers



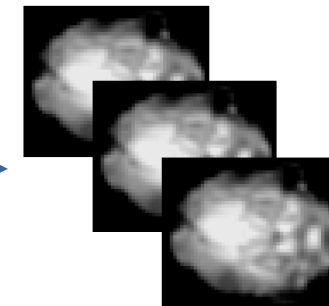
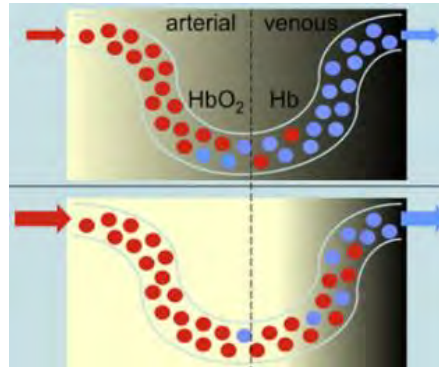
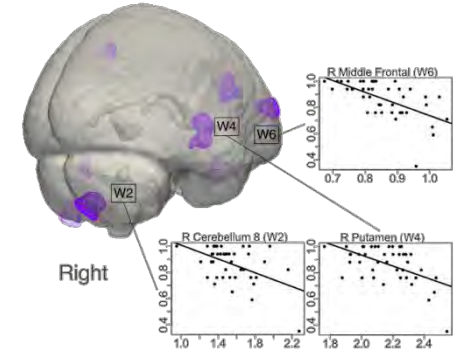
A Multi-Level Perspective



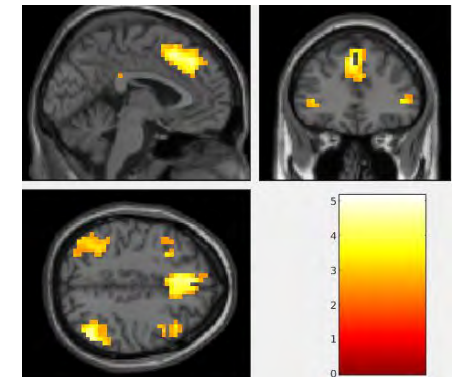
Magnetic Resonance Imaging (MRI)



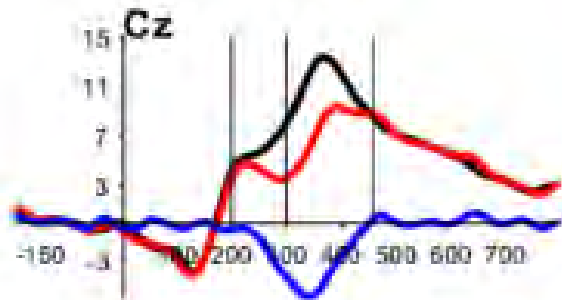
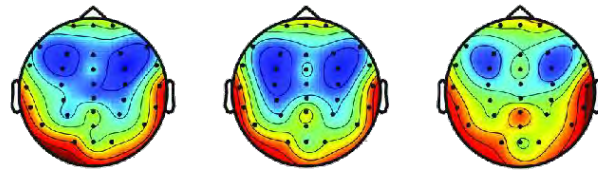
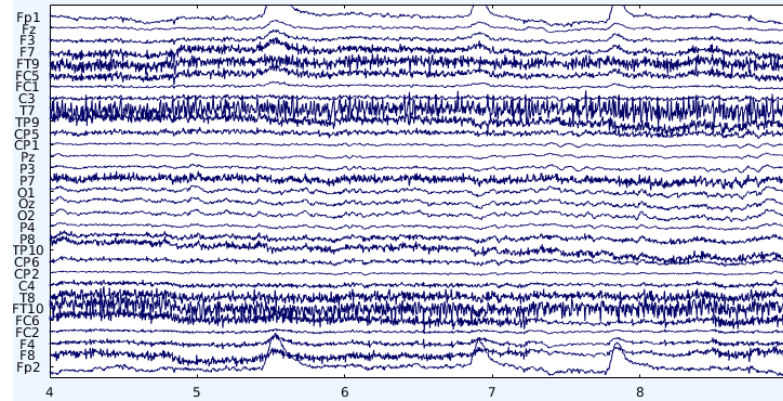
Structural



Functional



Electroencephalogram (EEG)



Other methods ...



fNIRS



Eye
tracking



VR



GSR

Educational Neuroscience Research & Training at UA

- PhD Concentration in Educational Neuroscience (since 2014)
- Educational Neuroscience BSc Major (since 2020)
- Labs conducting research on:
 - Mathematical learning and cognition
 - Reading and language development
 - Moral psychology and ethical development
 - Autism
- Collaborations with other departments & institutions

<https://edneuro.ua.edu>

MRI research facility!



What is learning?

- Permanent changes in behavior
- Memory consolidation
- Active construction of mental structures
- Structural changes in the nervous system
- **Adaptive changes in the entire organism to improve action possibilities in the environment**

Grounded
Cognition

Embodied Cognition

Situated
Cognition

4E
Cognition

Ecological
Psychology

Enactivism

Embodied, Embedded, Enacted, or Extended

Phenomenology

Pragmatism

Embodied Cognition

- Cognition is grounded in corporeal & sensorimotor systems
- Affordances and perception-action loops
- Representation free accounts
- Soft and dynamic assemblies of neural and bodily systems
- Sensorimotor simulations



Embodied Mathematics



What is numerosity?





Sensorimotor origins of number sense

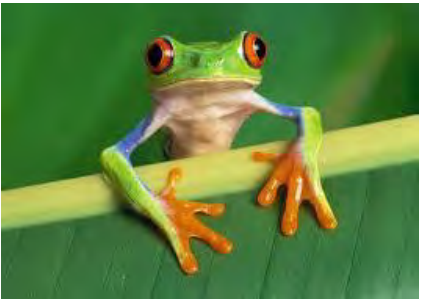
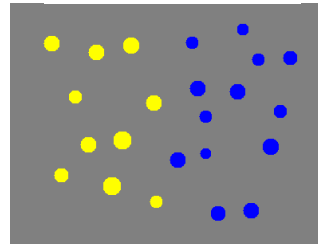
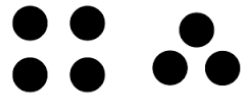
“... isolating something from the experiential continuum is an indispensable prerequisite for any conception of number”
(Steffe et al. 1988, p.3)

- Perceiving discrete objects by abstracting aspects ongoing sensorimotor experience (Glaserfeld, 1981).
- By 2 years use of the plural form of labels.
- **Fingers provide first experiences with plural forms**

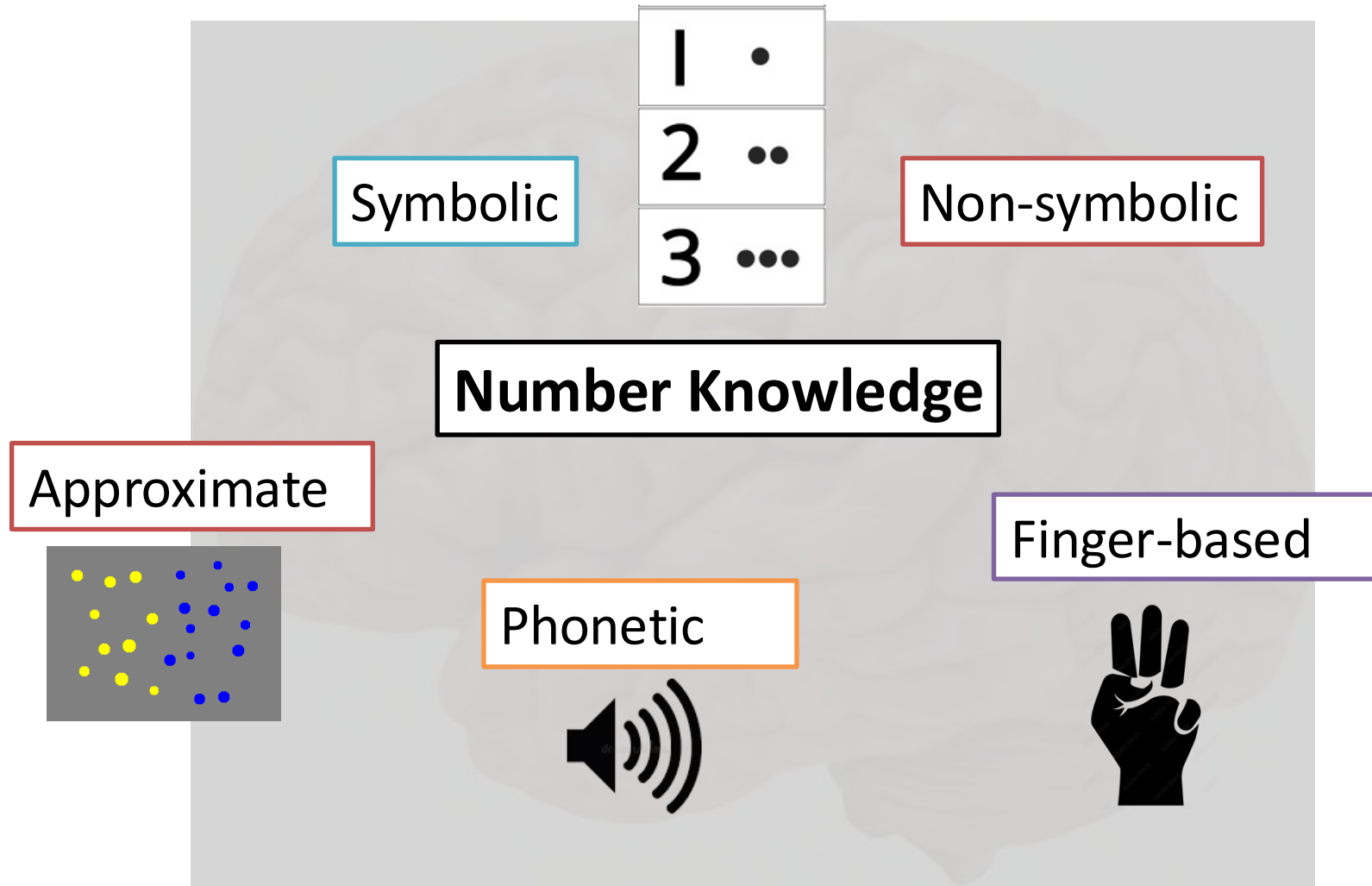


Numbers help in finding food & not becoming food, and mating

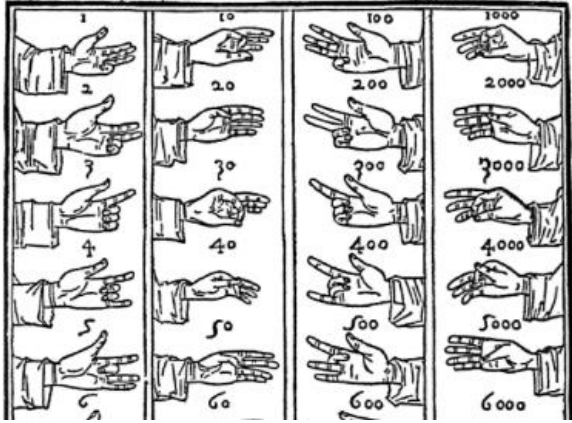
- Two number systems in non-human animals:
 - The object tracking system
 - Approximate number system



What makes us special?



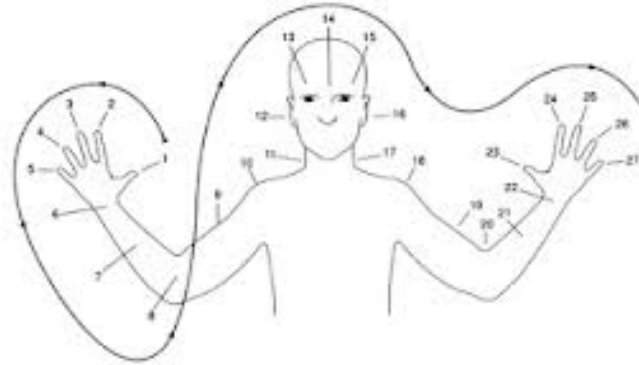
Body-Based Numbers Across Cultures



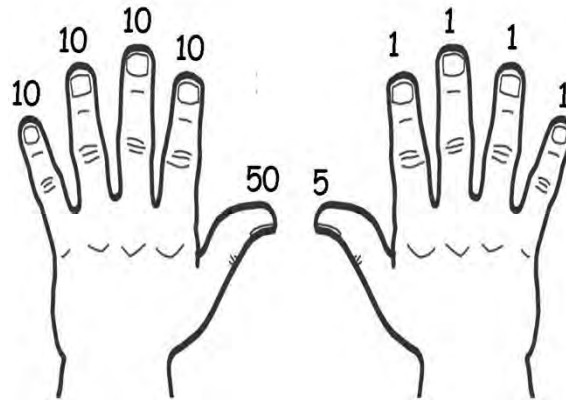
Bede's system - Medieval Europe



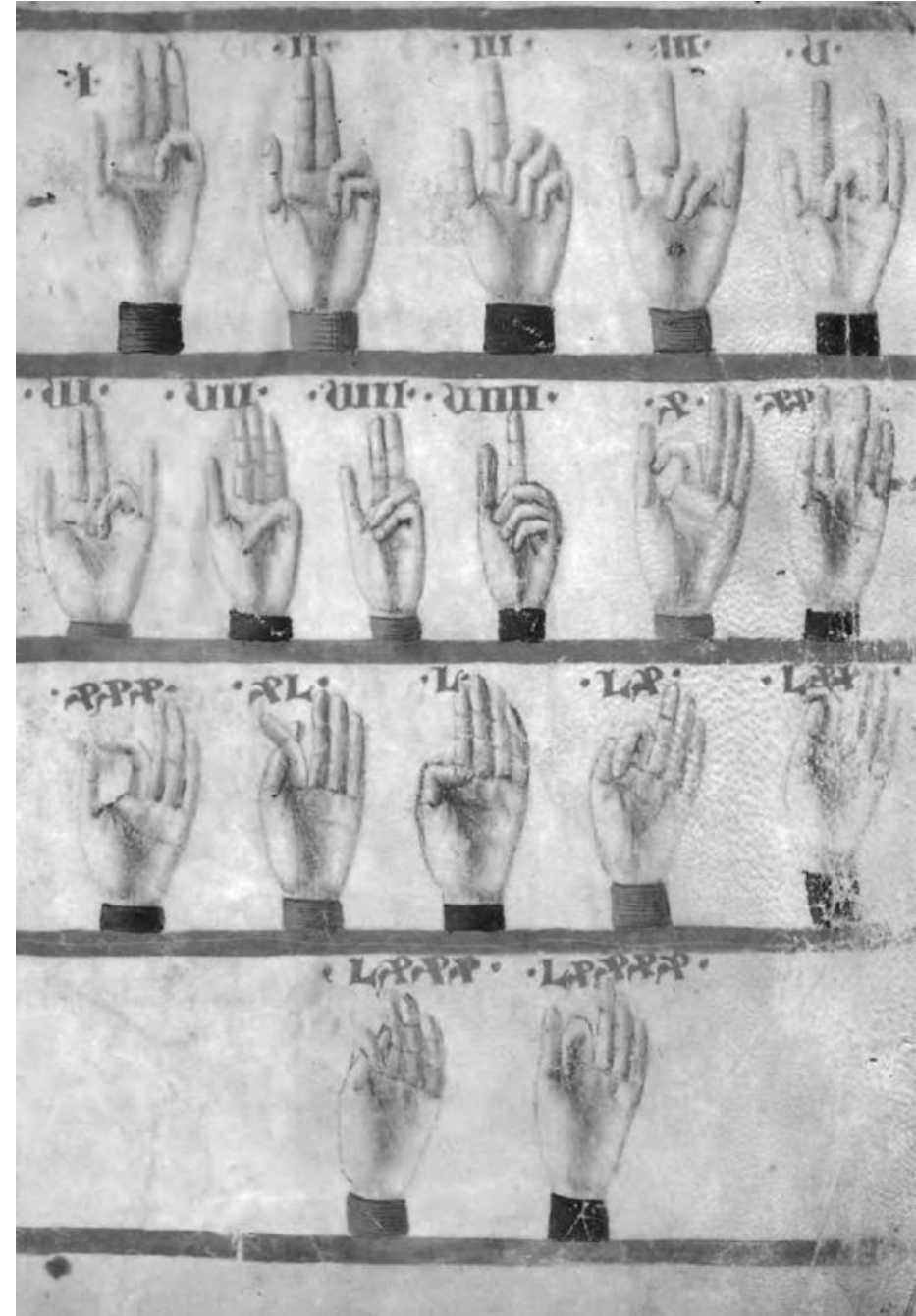
Japanese Soroban



Oksapmin counting system New Guinea (Saxe 1982)



- Korean Chisenbop



Liber Abaci (Fibonacci,

Hands & Numbers

- Children, across cultures, learn counting and arithmetic on their fingers
- Early finger-based experiences help shape the number processing skills



Finger Counting & Arithmetic Learning

- In K to 1st grade finger use & starting 2nd grade retrieval correlate with math performance (Jordan et al., 2008)
- Children with math difficulties use less efficient finger counting strategies and have difficulty switching to verbal counting & retrieval (Bryant, 2009)



20
Mental Arithmetic - Nikolay Bogdanov (1895)

Stroop-like physical-numerical magnitude interaction

Andres, Ostry, Nicol, & Paus (2008). Number magnitude and grip aperture interaction;

Badets, Andres, Di Luca & Pesenti (2007). Number magnitude potentiates action judgments

rTMS over left AG disrupts access to finger schema and number processing

Rusconi, Walsh & Butterworth (2005). Dexterity with numbers: rTMS over left



Finger discrimination (gnosis) predicts math ability

Noel (2005). Finger gnosis: a predictor of numerical abilities in children?; Newman (2016). Does finger sense predict addition performance?



Finger discrimination training improves subitizing, counting & ordinality judgment

Gracia-Bafalluy & Noel (2008). Does finger training increase young children's numerical performance?

Finger discrimination induces overlapping neural activity with mental arithmetic

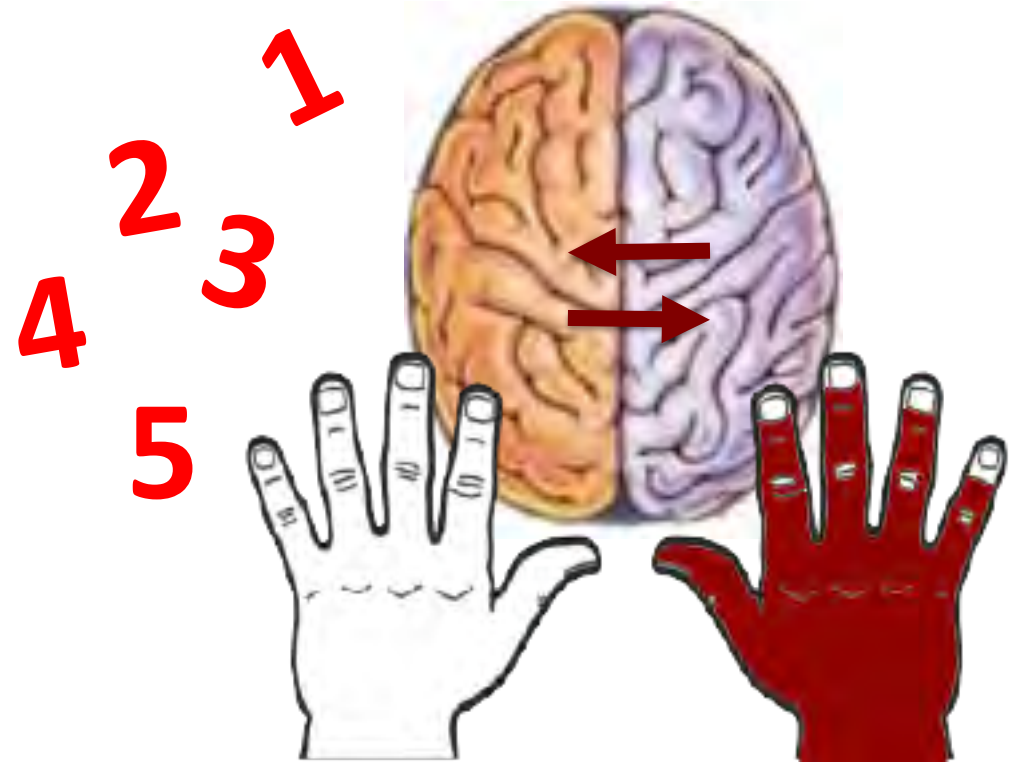
Andres, Michaux, N & Pesenti (2012). Common substrate for mental arithmetic and finger representation in the parietal cortex; Zago, et al. (2001). Neural correlates of simple and complex mental calculation.

Excitability of right hand muscles in counting & parity tasks

Sato, Cattaneo, Rizzolatti, & Gallese (2007). Numbers within our hands: Modulation of corticospinal excitability of hand muscles during numerical judgment. Andres, Seron, & Olivier. (2007). Contribution of hand motor circuits to counting.



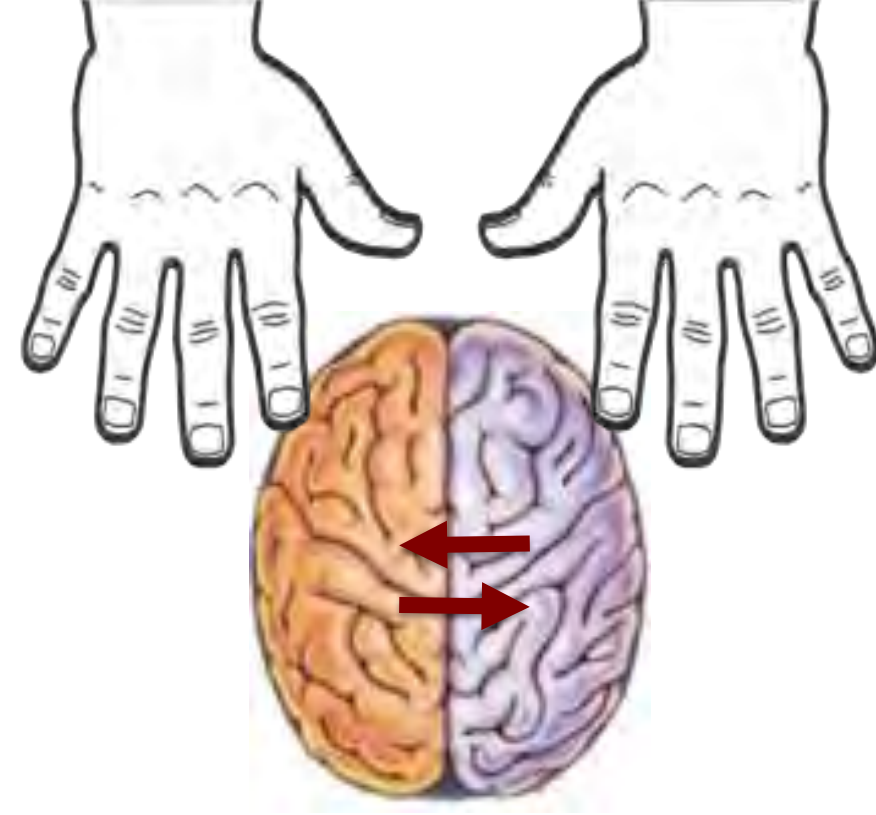
- Small numbers (1-5) lead to pre-motor/motor activation in the contralateral hemisphere.



Tschentscher, N., Hauk, O., Fischer, M., & Pulvermüller, F. (2012). You can count on the motor cortex: Finger counting habits modulate motor cortex activation evoked by numbers. Neuroimage,

Finger counting habits

- Higher performance for right-starters than left-starters.
-
- No intelligence differences between groups



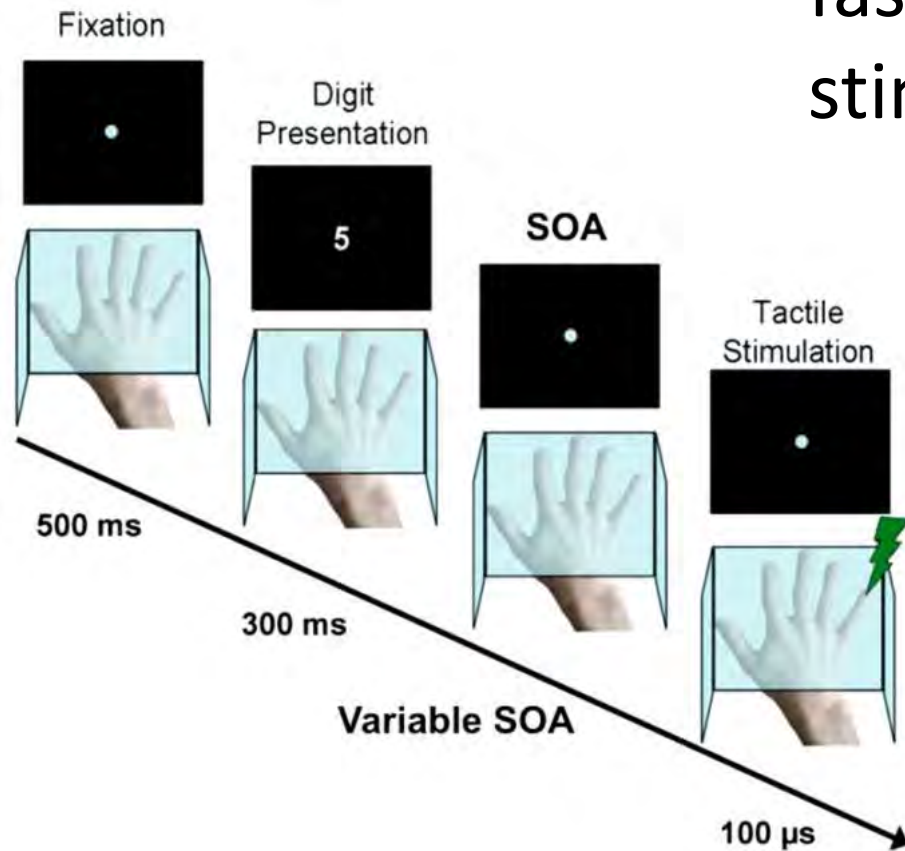
Greater need for hemispheric coordination



Slower processing (adults) or accuracy (children)

Newman & Soylu (2014). The impact of finger counting habits on arithmetic in adults and children. *Psychological Research*.

- Finger-number stimulus match fastens responses to sensory stimulation.



Brozzoli, C., Ishihara, M., Gobel, S. M., Salemme, R., Rossetti, Y., & Farne, A. (2008). Touch perception reveals the dominance of spatial over digital representation of numbers. *PNAS*

Finger Tapping & Number Processing

- Number processing uses more shared resources with finger tapping than language processing.
- Anatomical tapping uses more shared resources with easy addition than hard.
- Angular gyrus participates both in easy-addition and tapping.

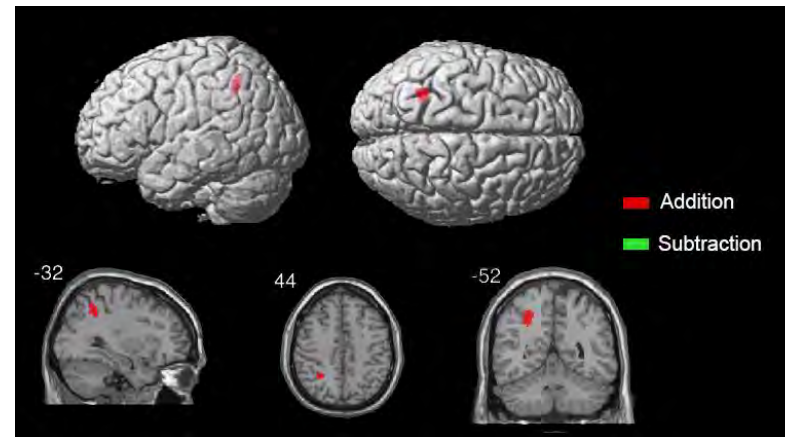
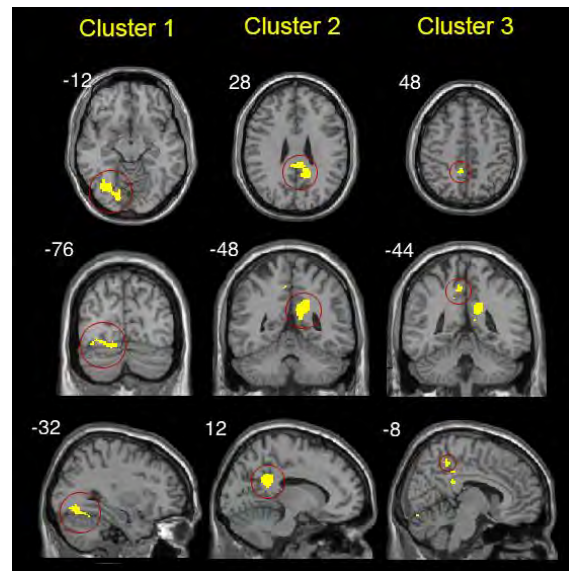
Left AG



Soylu, F., Newman, S.D. (2016). Anatomically ordered tapping interferes more with one-digit addition than two-digit – A Dual-Task fMRI Study. *Cognitive Processing*.

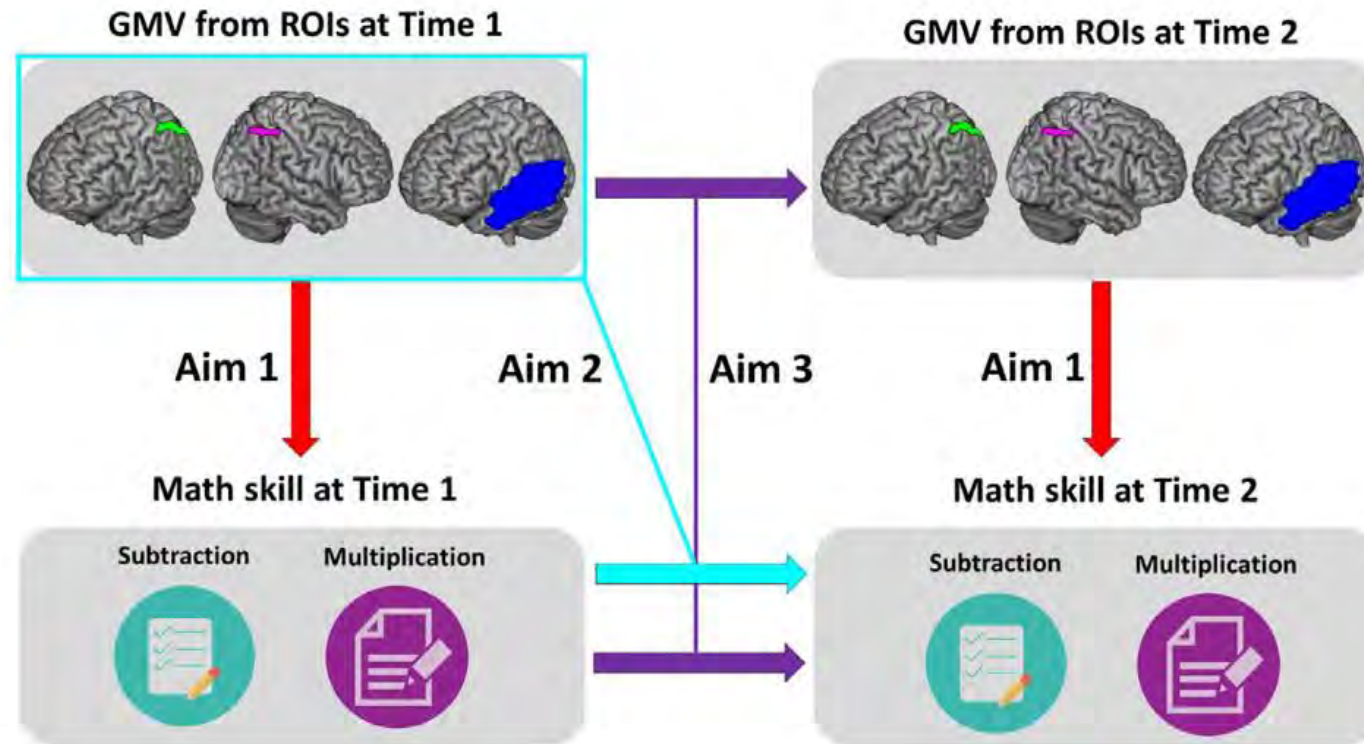
Finger gnosis negatively correlates with activation in functional networks for mental arithmetic

Soylu, F., Raymond, D.R., Gutierrez, A.M., & Newman, S.D. (2018). The differential relationship between finger sense, and addition and subtraction: an fMRI study. *Journal of Numerical Cognition*



GMV in the left IPS predicts subtraction gains

Suárez-Pellicioni, M., Soylu, F., & Booth, J. R. (2021). Gray matter volume in left intraparietal sulcus predicts longitudinal gains in subtraction skill in elementary school. *NeuroImage*



Educational Interventions Inspired by Research



Educational Studies and Interventions

- Piaget's constructivism
- Manipulatives (e.g., Cuisenaire rods)
- Papert's constructionism
- Neuroconstructivism
- Embodied design



Structured versus free block play: the impact on arithmetic processing

Effects of structured- vs. free-block play on arithmetic performance in 3 & 4 graders.

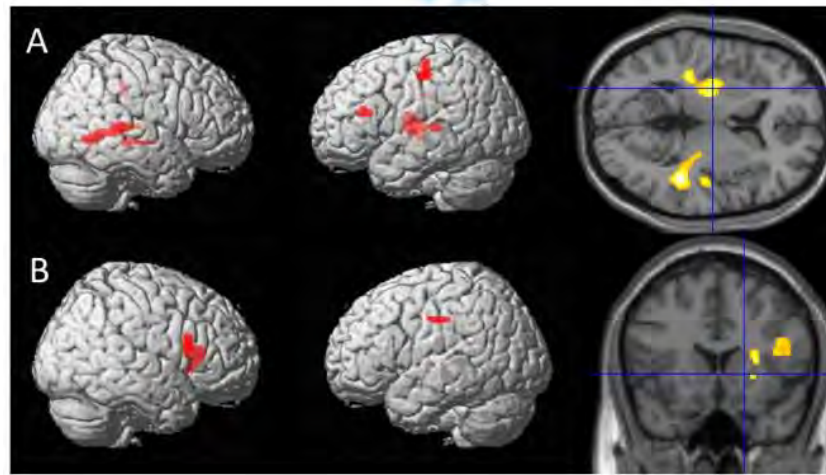


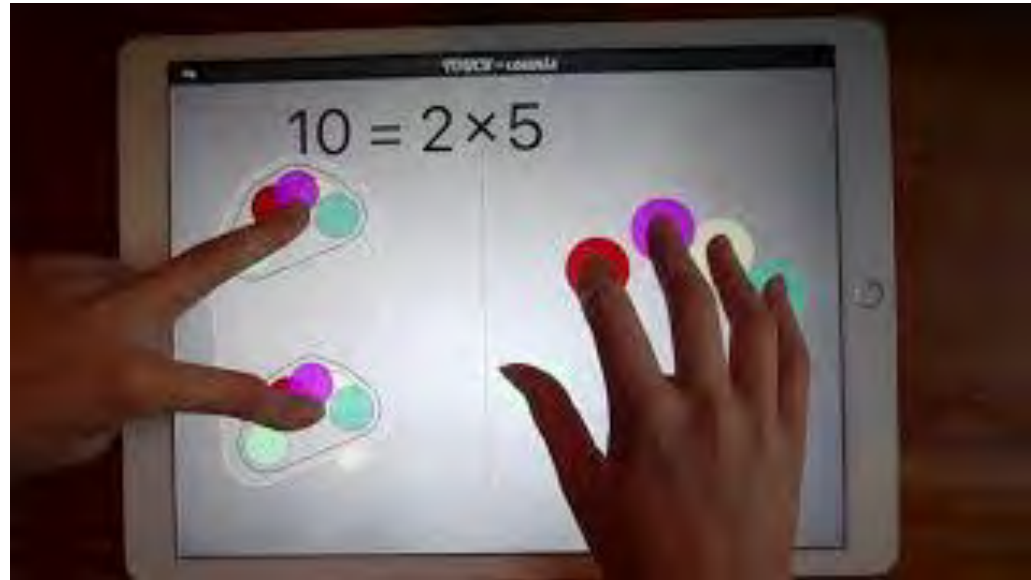
Figure 4: Structured Block Play: (A) Depicts activation increases after structured block play for addition. (B) Depicts activation increases after structured block play for subtraction.

Mathematical Imagery Trainer



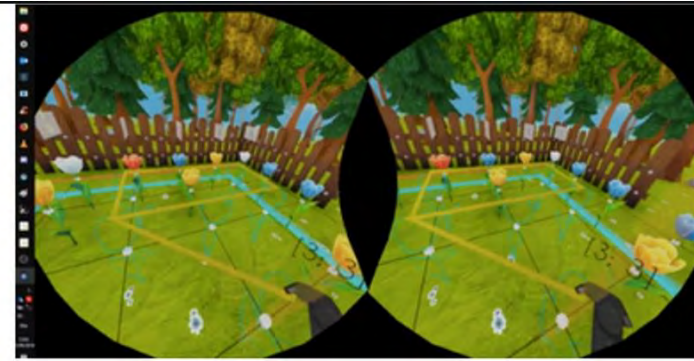
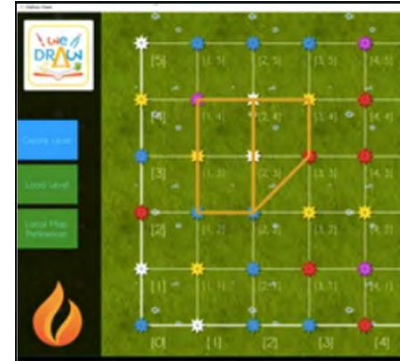
Abrahamson, D., & Trninic, D. (2015). Bringing forth mathematical concepts: Signifying sensorimotor enactment in fields of promoted action. *ZDM*, 47(2), 295-306.

Digital Math Manipulatives



Bakos, S., Pimm, D (2020). Beginning to Multiply (with) Dynamic Digits: Fingers as Physical–Digital Hybrids. *Digit Exp Math Educ.*

Tangible Computing & Embodied Mathematics



Price, S., Yiannoutsou, N., & Vezzoli, Y. (2020). Making the Body Tangible: Elementary Geometry Learning through VR. *Digital Experiences in Mathematics Education*

Thank you!

شكراً جزيلاً



Brain Awareness AUC Conference 2023



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