Expanding Understandings of Embodied Mathematical Cognition in Students' Fraction Knowledge

School of Education
UNIVERSITY OF WISCONSIN–MADISON

Kelsey E. Schenck, Michael I. Swart, Edward M. Hubbard, and Mitchell J. Nathan
University of Wisconsin - Madison, Department of Educational Psychology

NIH Eunice Kennedy Shriver National Institute of Child Health and Human Development

ABSTRACT

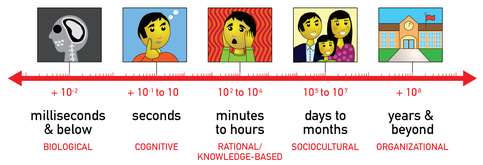
This study provides evidence that middle-grade students' symbolic fraction knowledge relates to grounded and embodied cognitive learning processes such as spatial ability and anxiety. These findings are consistent with previous findings[1,2] while highlighting several novel associations: 1) Mental rotation and spatial visualization are specifically predictive of fraction knowledge scores; 2) Spatial anxiety may moderate the relationship between spatial ability and fraction knowledge scores; and 3) Fraction knowledge is not only grounded in processes operating at biological and cognitive timescales individually but components of these processes are interconnected.These findings may provide the foundations for future work exploring the mechanisms behind these associations.

THEORETICAL BACKGROUND

We draw on the Grounded and Embodied Learning Framework[3], which describes the interconnected nature of learning across timescales including:

***biological**
(affective states & memory)

***cognitive**
(spatial ability & number sense)

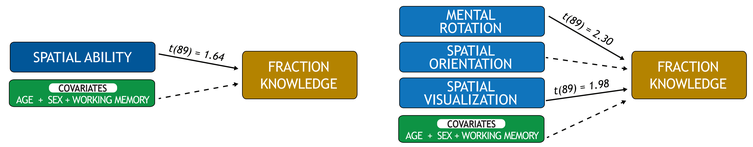


RESEARCH QUESTION 1 RESULTS

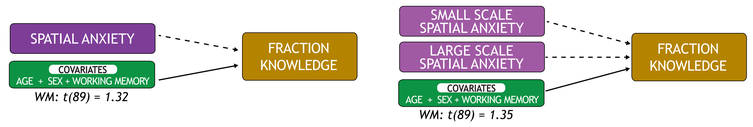
What are the relationships between spatial anxiety, spatial ability, and performance on fraction assessments?

We used ordinary least square requression to fit a series of models to predict scores of the fraction knowledge assessment by:

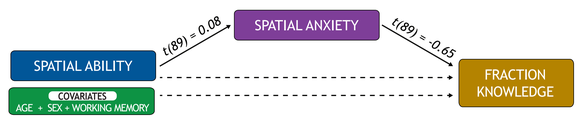
SPATIAL ABILITY



SPATIAL ANXIETY



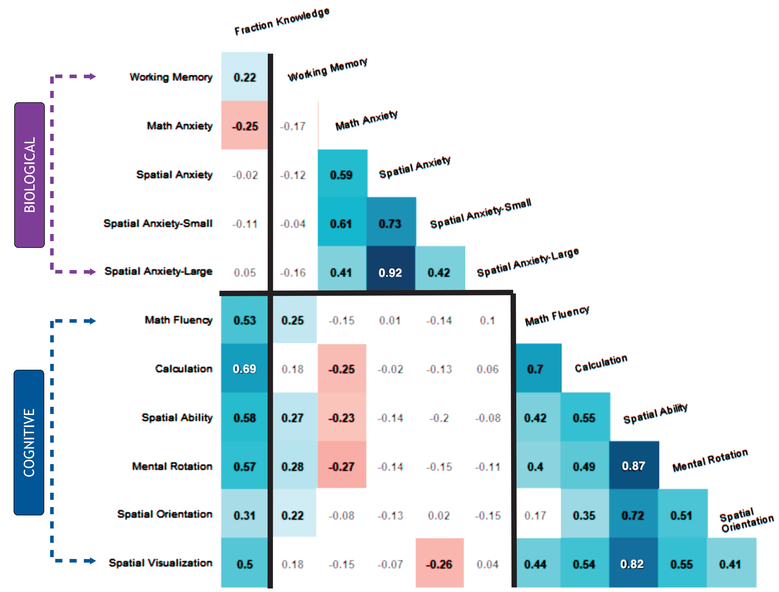
INTERACTION



RESEARCH QUESTION 2 RESULTS

How are mathematical learning and thinking about fractions rooted in body-based processes?

We used caluated Pearson's correlations to estimate magnitude and direction of the relationships between variables across embodied processes including:



METHODS

PARTICIPANTS:

- 4th year of a longitudinal study
- N = 89
  - Female (38%), No answer (6%)
  - 5th grade (62%), 8th Grade (38%)

PROCEDURE:

- Two 2-hour sessions to complete assessments (in-person or virtual)
- Interrupted due to COVID-19

MEASURES:

- **Fraction Knowledge Assessment**

BIOLOGICAL
- **Woodcock-Johnson Tests III**
  - Auditory Working Memory
- **Math Anxiety Rating Scale**
- **Spatial Anxiety**
  - Large Scale, Small Scale

COGNITIVE
- **Woodcock-Johnson Tests III**
  - Math Fluency, Calculation
- **Spatial Reasoning Instrument**
  - Mental Rotation, Orientation, Visualization

DISCUSSION

- **Spatial ability,** specifically spatial visualization and mental rotation skills, are signifcantly **predictive of symbolic fraction knowledge** and may be **moderated by spatial anxiety.**

- These associations may be indicative of how students **ground fraction knowledge** in a non-symbolic **ratio processing system**[4] and evidence a link between **mental rotation and SNARC effect magnitude**[5].

- Both **biological and cognitive embodied processes**[3,6] were **correlate with learning and thinking about fractions.** Though many fraction knowledge researchers focus on one single variable, these correlations may **indicate additional variables and relationships** of interest in future work.

REFERENCES

[1]DeWolf, M., Bassock, M., & Holyoak, K. J. (2015). From rational numbers to algebra: Separable contributions of decimal magnitude and relational understanding of fractions. *Journal of Experimental Child Psychology, 133,* 72 - 84.
[2]Toomarian, E. Y., & Hubbard, E. M. (2019). Individual differences in implicit and explicit spatial processing of fractions. *Frontiers in Psychology, 10,* 596.
[3]Nathan, M. J. (2021). *Foundataions of embodied learning: A paradigm for education.* Routledge.
[4]Park, Y., & Matthews, P. G. (2021). Revisiting and refining the relations between nonsymbolic ratio processing and symbolic mathematics achievement. *Journal of Numerical Cognition, 7,* 328 - 350.
[5]Viarouge, A., Hubbard, E. M., & McCandliss, B. D. (2014). The cognitive mechanims of the SNARC effect: an individual differences approach. *PloS one, 9,* e95756.
[6]Newell, A. (1994). Unified theories of cognition. Harvard University Press.

ACKNOWLEDGEMENTS

This research was supported by grants from NICHD to Edward M. Hubbard and Percival G. Matthews (R01 HD088585), and a core grant to the Waisman Center (U54 HD090256). The opinions expressed here are those of the authors and do not represent views of NICHD or the Waisman Center. Study data was collected and managed using REDCap electronic data capture tools hosted at UW-Madison.

For more information, please contact: keschenck@wisc.edu