**INTRODUCTION**

How do abstract mathematical concepts gain meaning?

Contemporary cognitive science research suggests that numbers and the arithmetic operations performed on them are grounded in innate perceptual and motor systems. In addition to these two explanations, we propose adding a third mechanism—**formal anchoring**. This hypothesis emphasizes how abstract numbers and arithmetic operations themselves can themselves bootstrap an understanding of higher-level concepts and procedures. In this way, the abstract becomes concrete.

**DOMINANT THEORIES**

Dominate accounts of numerical and arithmetic development emphasize the recruitment, repurposing, and refinement of perceptuo-motor and visuospatial systems (Blair, Tsang, & Schwartz, 2013; Landy, Allen, & Zednik, 2014; Siegler, 2016).

**FORMAL ANCHORING HYPOTHESIS**

1. Formal anchoring is the task-specific recruitment of more concrete representations.

2. It is used to alleviate computational and working memory demands.

3. The benefits of formal anchoring are task-specific. It is sometimes necessary for successful performance. In some cases, however, it merely improves how quickly the goal state is reached.

4. To explain why particular concrete mathematical concepts are appropriate on some tasks but not others, it is useful to focus on the alignment between what a task demands and what a representation provides. An appropriate representation simplifies a task without altering its underlying nature.

**GAPS & GOALS**

Current theories of numerical and arithmetic cognition are specific to particular tasks and number systems. To date, it is unclear how well existing theories generalize across task types and number systems. We seek a theory of mathematical cognition robust enough to:

1. Explain mathematical cognition phenomena across multiple ecologically valid tasks and number systems of varying abstraction.


3. Extend mathematical cognition research to higher-level topics like complex numbers, algebra, and calculus.

To construct such a theory, we reviewed numerical cognition literature discussing how natural numbers, integers, and rational numbers are understood by people of differing ages. In addition, we supplemented the review with our own study examining the cognitive bases of irrational numbers (Patel & Varma, in press).

**FUTURE RESEARCH**

1. Which cognitive and environmental factors promote the discovery and use of formal anchors?

2. Is the use of formal anchors always more efficient?

3. What are the neural bases of formal anchoring?

4. How well can formal anchoring explain mathematical cognition specific to more complex domains like algebra and calculus?