Cognition under Pressure: Relationships between Anxiety, Executive Functions, and Mathematics

Emily McLaughlin Lyons[a] (ealyons@uchicago.edu) & Lindsey E. Richland[a]
[a]Department of Comparative Human Development, University of Chicago, Chicago, IL,60637
Priti Shah[b] (priti@umich.edu) & Amira Ibrahim[b]
[b]Department of Psychology, University of Michigan, Ann Arbor, MI, 48109
Marci S. DeCaro[c] (marci.decaro@louisville.edu), David B. Bellinger[c] & Patricia A. S. Ralston[d]
[c]Department of Psychological and Brain Sciences, University of Louisville, Louisville, KY, 40292
[d] Department of Engineering Fundamentals, University of Louisville, Louisville, KY, 40292
Susanne M. Jaeggi[e] (smjaeggi@uci.edu)
[e]School of Education, University of California, Irvine, 3452 Education Building, Irvine, CA, 92697

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Introduction

This symposium integrates findings across studies conducted in both laboratory and classroom contexts to draw attention to the relationships between Executive Functions (EFs) and feelings of anxiety in a context with educational consequences: Mathematics. EFs, the cognitive resources including working memory and inhibitory control that enable attentional control, manipulation of mental representations, and task switching (Miyake et al, 2000), powerfully predict mathematics achievement (Bull & Lee, 2014). Mathematics is also a domain in which anxiety and performance pressure are often heightened, which can result in worry ideation and load to EF resources (Foley et al, 2017; Schmader & Beilock, 2012). However, despite these relationships, mathematics cognition under pressure remains under-considered.

Session Overview

In this symposium, panelists each examine relations between mathematical thinking and EFs, and/or anxiety. The overall aims of the symposium are to both better clarify the mechanisms underpinning complex mathematical thinking, as well as to identify leverage-points for using individual difference data to develop intervention strategies to optimize mathematics instruction. Participants engage with this question from a diversity of approaches, examining basic number concepts, mathematics, and engineering content domains, in child, adolescent, and adult populations- in both classroom and laboratory study contexts.

Jaeggi reports experiments using an EF and number training design to clarify the relationships between number magnitude skills (a foundation of early mathematics), EFs (a domain general mechanism) and early numerical skills (domain-specific), finding that both trainings improve numerical cognition. **Lyons** and **Richland** report on experimental manipulations of stereotype threat and pressure, revealing that these stressors can reduce cognitive engagement in a mathematics lesson, likely by loading EF resources. **DeCaro** reports on two experiments revealing that trait mindfulness can reduce the impacts of pressure and anxiety on test performance. Finally, **Shah** and **Ibraham** demonstrate that individuals with high math anxiety or low knowledge may select low demand study techniques but may learn the most from high demand techniques.

In total, this symposium integrates across a wide range of talks to develop new insights into the relationships between EFs, pressure/ anxiety, and mathematics learning. The symposium will clarify how these mechanisms are interrelated, and the moderator, Richland, will draw the audience into a discussion of future directions for the field and leverage points for education, time permitting.

Effects of Domain-general and Domain-specific Training on Numerical Cognition (Jaeggi)

Providing children with a strong foundation in mathematics is of critical importance since early number knowledge is highly predictive for later scholastic achievement. In this talk, I will report the results of several experiments in which we trained kindergartners on an intervention that targeted either their working memory or their understanding of numerical magnitudes. Our data show that both interventions improve children's numerical magnitude knowledge, providing evidence for the theory that both domain-specific and domain-general skills contribute to the development of children's numerical knowledge. Furthermore, our data also suggest that individual differences in executive functions predict training outcomes, and as such, targeting those functions directly could leverage learning outcomes across a broad range of domains including math.

Impacts of Stereotype Threat and Pressure on Math Learning (Lyons & Richland)

Stereotype threat and pressure can lead to intrusive thoughts and worries that tax EF resources (Schmader & Beilock, 2012) and are well-known to harm test performance. In this talk, we describe results from two studies examining how experiencing stereotype threat or pressure during a cognitively demanding conceptual math lesson impacts initial learning.

In both studies, students viewed a videotaped lesson on ratio, with stereotype threat or pressure manipulated before instruction. In Study 1, 135 predominantly minority 5th grade students (83% African American, 17% LatinX; 71 girls) were randomly assigned to provide either their race or the date before the lesson. Students who gave their race retained less learning when measured at a 1-week delay, with the greatest detrimental impact seen among students with high baseline EF resources who otherwise learn the most from this lesson. Participants in Study 2 were 178 diverse 5th grade students (33%African American, 27%White, 26% LatinX, 13% Biracial; 88 girls). Before the lesson, half the participants were told that they would later be taking a test on the lesson's content and their entire class would receive a desired incentive (or not) based on how well they performed. The pressure manipulation did not impact boy's learning, but girls assigned to the pressure condition retained less learning over time. This pattern of findings suggests that engagement of EF resources in worry ideation about performance or being judged stereotypically may interfere with students' ability to engage deeply with conceptual math instruction in ways that promote enduring conceptual math understanding.

Mindfulness and Test Anxiety in Undergraduate Engineering Mathematics (DeCaro, Bellinger &Ralston)

High-stakes testing environments can lead to worries and negative ruminations that co-opt working memory resources, reducing mathematics performance. For example, students in undergraduate engineering mathematics courses frequently report test anxiety, which is associated with lower grades. We examined whether dispositional mindfulness may serve as a buffer to the effects of test anxiety by improving emotion regulation in stressful test settings. In Study 1, we examined mathematics performance in a high-pressure laboratory setting. Mindfulness indirectly benefited mathematics performance by reducing the experience of state anxiety. This benefit occurred selectively for problems that required greater working memory resources. Study 2 extended these findings to a calculus course taken by undergraduate engineering majors.

Mindfulness indirectly benefited students' performance on high-stakes quizzes and exams by reducing their cognitive test anxiety. Mindfulness did not impact performance on lower-stakes homework assignments. These findings reveal an important mechanism by which mindfulness benefits mathematics performance: mindfulness may reduce the negative impact of anxiety about performance, enabling students to more fully devote working memory resources to the test.

The role of individual differences when studying mathematics (Shah & Ibrahim)

Decades of research demonstrate that cognitively demanding study strategies can act as "desirable difficulties" facilitating long-term retention (Bjork, 1994). In two studies, we aim to 1) gain a better understanding of the factors that shape student's likelihood of using cognitively demanding study strategies, and 2) determine if individual differences in working memory (WM) capacity, math skill or math anxiety shape the effectiveness of high vs low demand study strategies. In study 1, 293 undergraduate students completed measures of math anxiety and study strategies. We found that high math anxious individuals were more likely to use low demand study strategies such as rereading and less likely to use high demand study strategies such as elaboration. In study 2, 194 college students were taught base number conversions and randomly assigned to study the computation either using worked out examples (lower WM demand) or actively problem solving (high WM demand). After a five-minute break, individuals completed a final test consisting of eight novel base number conversion problems. Studying worked examples was less effective for individuals with low math skills, who also had lower WM capacity and higher math anxiety. Together, results from studies 1 and 2 suggest that math anxious students, who tend to have lower math achievement, are selecting to use study strategies that are low in "desirable difficulty" and WM demand, though they might benefit the most from the more demanding, active problem solving.

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