Developmental Review 62 (2021) 100997

Contents lists available at ScienceDirect

Developmental Review

journal homepage: www.elsevier.com/locate/dr

Development of children's math attitudes: Gender differences, key socializers, and intervention approaches

Susan C. Levine [*], Nancy Pantoja

Department of Psychology, University of Chicago, United States

ARTICLE INFO

Keywords:
Math attitudes
Math achievement
Math anxiety
Math-gender stereotypes
Math self-concept
Mindsets

ABSTRACT

The relation of various math attitudes to math achievement has been extensively studied in adolescents and adults. Recently, researchers have begun to examine the math attitude-math achievement relation in young children. We review theories and research on four attitudes relevant to early math learning—math anxiety, math self-concept, mindset, and math-gender stereotype. These attitudes emerge and are related to math achievement by early elementary school. Our review suggests that early math achievement plays an important role in the initial development of either positive or negative math attitudes, which in turn, may initiate a vicious or virtuous cycle that can enhance or undermine math learning. Additionally, gender differences in math attitudes (favoring boys) emerge by early to mid-elementary school. An important future direction involves understanding how early attitudes about math relate to each other, and whether certain constellations of attitudes are prevalent. We also consider three types of math attitudes that key socializers—parents and teachers—hold: general (math-gender stereotypes and mindsets), self-relevant (math anxiety), and child-specific (expectations and value of math for their child or student). Our review highlights a link between key socializers' math attitudes and associated behaviors, and their children's math attitudes and math achievement. Based on these findings, we propose the Early Math Achievement-Attitude model (EMAA). An important future direction involves increasing our understanding of how key socializers with different math attitude constellations engage with children around math. Finally, based on our review of these topics as well as intervention studies, we discuss intervention approaches that hold promise for improving young children's math achievement and math attitudes.

Introduction

Mathematical skills and course-taking are important predictors of life outcomes, including health and earnings (Murnane et al., 1995; Rose & Betts, 2004; National Mathematics Advisory Panel, 2008; Reyna & Brainerd, 2007). Nonetheless, mathematics (referred to as math) is a polarizing discipline, with some individuals identifying and others disidentifying as "math people". Many people fall into the latter group, and the roots of this disidentification can start early in life. Moreover, this disidentification is not evenly distributed across social groups, including gender groups. Women have more negative math attitudes than men, are stereotyped to have low math ability, and are underrepresented in science, technology, engineering, and math (STEM) fields, particularly physical

* Corresponding author at: Department of Psychology and Committee on Education, Rebecca Anne Boylan Professor in Education and Society, University of Chicago, 5848 S. University Avenue, Chicago, IL 60637, United States.

E-mail address: s-levine@uchicago.edu (S.C. Levine).

https://doi.org/10.1016/j.dr.2021.100997
Received 29 January 2021; Received in revised form 28 September 2021;
Available online 26 October 2021

sciences, engineering and computer science (Blickenstaff, 2005; OECD, 2006, 2012, 2017; Stoet & Geary, 2018). This gender gap in math and STEM participation not only raises important issues about equity in access to STEM careers, but also decreases the size of the STEM workforce and curtails innovations that benefit from diverse points of view.

While many researchers argue that the underrepresentation of women in STEM careers is due to gender differences in math ability, there are multiple indications that the gender difference in math achievement may be at least partly due to other factors. Notably, the gender difference in math achievement is small, variable with respect to time and place, and not present at early ages. In terms of time variability, the male advantage is smaller in recent cohorts (J.R. Cimpian et al., 2016; Else-Quest et al., 2010; Hyde, Fennema, & Lamon,1990; Hyde, 2005; Hyde & Mertz, 2009; Miller & Halpern, 2014; Wai et al., 2010). With respect to place variability, the magnitude of gender differences on standardized math test scores differs widely across different countries (Else-Quest et al., 2010), perhaps due to differences in gender equity, although there is disagreement about whether more equitable countries have a smaller or a larger male advantage (Guiso et al., 2008; Hamamura, 2012; Stoet & Geary, 2013; Stoet et al., 2016).

Further, even though some studies report more males than females in the upper tail of the distribution (e.g., Stoet & Geary, 2013; Wai et al., 2010), this may not reflect an immutable difference in math ability but rather may reflect gender differences in math attitudes and associated experiences, which favor males. In addition, girls tend to earn higher grades in math courses throughout schooling, and grades may be more or equally predictive of important outcomes such as college completion than test scores (Allensworth & Clark, 2020; J.R. Cimpian et al., 2016; Duckworth & Seligman, 2006; Felson & Trudeau, 1991; Jordan et al., 2006; Miller & Halpern, 2014; Pomerantz et al., 2002; Stoet & Geary, 2013).

Finally, in terms of development, there is no indication that math test scores or math-related neural activity differs between young boys and girls, suggesting that later gender differences in math test scores may emerge due to factors other than a gender difference in math ability (Hyde et al., 2008; Kersey et al., 2018; 2019; Spelke, 2005). Even though there is evidence of an early-emerging gender-related difference in spatial skill, which is related to differences in math achievement, disparities in spatially relevant experiences may contribute to this difference (see Herts & Levine, 2020; Levine et al., 2016 for review; Mix et al., 2016).

In light of these findings, our review examines the possibility that gender differences in early emerging beliefs, feelings, and motivations about math (referred to as "math attitudes" for simplicity sake) may contribute to females' lower math achievement outcomes, which are likely linked to lower participation in STEM fields. There is evidence that these attitudes are more negative in females than males. Importantly, math attitude gender differences emerges early in development and could play a role in establishing a virtuous or vicious math attitude * math achievement cycle (Gunderson, Park, et al., 2018).

We examine the largely separate literatures on the development of four math attitudes that have been linked to math achievement as well as to important math choices and behaviors. We begin by reviewing research on the development of math anxiety and math self-concept, two self-relevant math attitudes that reflect how individuals think and feel about their own relation to math. We then turn to mindset about math ability and motivational framework (the broader motivations and behaviors associated with mindset) as well as to math-gender stereotypes, both of which are more general attitudes about math ability—whether it is a fixed endowment or malleable, and whether it is higher in males than females. For each of the math attitudes we review, we consider research examining a) when the attitude emerges and when it begins to relate to math achievement, math choices, and math-related behaviors, b) when gender differences in the attitude emerge, and whether the relation of math attitudes to math outcomes relation differs for boys and girls c) how key socializers contribute to the development of the attitude and its relation to math achievement and other math outcomes in boys and girls, and d) interventions that hold promise for improving the attitude and math outcomes. In addition, throughout our review, we strive to integrate findings from these literatures

Informed by findings discussed in our review, we propose the Early Math Achievement-Attitude model (EMAA model, see Fig. 1),

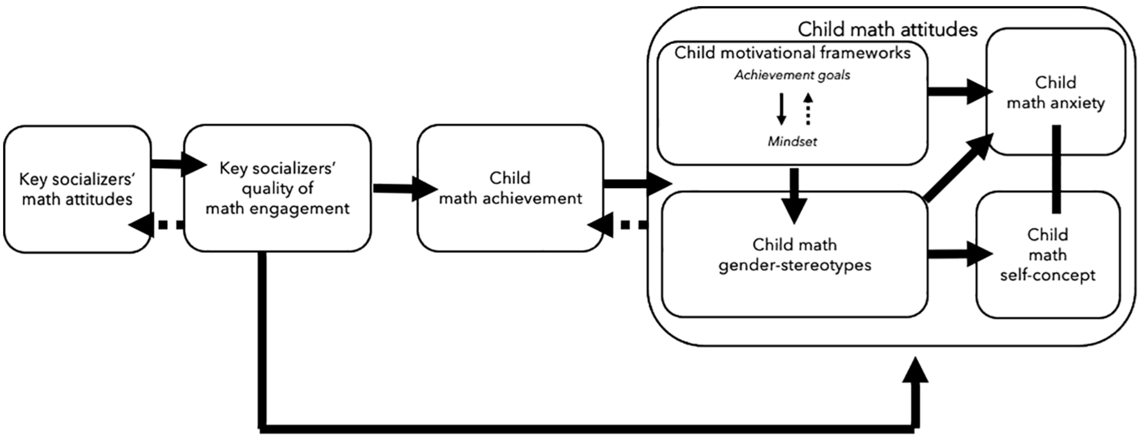

Fig. 1. Early Math Achievement-Attitude model (EMAA model): This model focuses on the early emergence of math achievement and math attitudes, and the relation between the two, and includes the role of key socializers' math attitudes and math engagement with children. For bidirectional relations, the earlier emerging relation is shown with a solid line and the later emerging relation is shown with a dotted line. A line with no arrows indicates that the direction of that relation is unclear. Note that future research may reveal additional relations.

which is unique in its focus on the emergence and development of math achievement * math attitude relations in young children. As shown on the left side of the figure, the model proposes that key socializers' math attitudes influence their math-relevant behaviors, including their engagement of children in math achievement-related experiences. These experiences, in turn, play a role in children's math learning and achievement. In addition, as shown in the model, when key socializers are supported in ways that help them engage in math with their children, this improves their child-specific math attitudes. As shown on the right side of the figure, children's math achievement first influences their math attitudes, with the link between achievement and attitudes becoming bidirectional as children develop. In addition, certain math attitudes are foundational to other math attitudes, serving as "hub" math attitudes.

With respect to gender differences, by early to mid-elementary school, boys have more positive math attitudes than girls. Further, key socializers—parents and teachers—contribute to these gender differences. Finally, although there has been little work focused on improving early math attitudes, we discuss intervention approaches that hold promise for fostering positive math attitudes and improving math achievement in young children. Against this backdrop, we highlight research directions that we believe could advance our understanding of the factors that contribute to the development of robust math learning and positive math attitudes, beginning as early as the preschool years.

Math anxiety

Math anxiety is a fear or nervousness that many people experience when they are doing or are even anticipating doing math (Hembree, 1990; Lyons & Beilock, 2012; Richardson & Suinn, 1972; Young et al., 2012). Math anxiety interferes with adults' ability to solve math problems in daily life and in academic situations (Ashcraft, 2002; Beilock et al., 2017; Hembree, 1990; Richardson & Suinn, 1972). It is thought to include a cognitive component that involves worrying about performance and about doing well in math, and an affective component that involves emotions of nervousness and tension (Wigfield & Meece, 1988).

Researchers have distinguished between the cognitive and affective components of math anxiety, and more recently between a math learning component (i.e., anxiety about being in a math learning situation) and a math evaluation component (i.e., anxiety about taking math assessments; Namkung et al., 2019; Barroso et al., 2020). However, it is possible that these components overlap, such that there may be both an affective component and a cognitive component in math learning situations as well as in math assessment situations. Some studies of children have examined only one of these components of math anxiety, while others have examined both the cognitive and affective components, both the math learning and math evaluation components, or components that do not fit these categories (Barroso et al., 2020; Namkung et al., 2019). Importantly, meta-analyses find that regardless of the component of math anxiety assessed, the pattern remains the same: higher math anxiety is associated with lower math achievement (Barroso et al., 2020; Namkung et al., 2019).

Whether different components of math anxiety develop along different trajectories is an open question. For example, it is possible that anxiety about learning math develops first, and then influences anxiety about being evaluated in math. Increasing our understanding of the development of different aspects of math anxiety would inform whether early interventions should focus on the cognitive or affective component of math anxiety, or both.

The negative relation between math anxiety and math achievement has been extensively studied in adolescents and adults (Hembree, 1990; Ma, 1999). In adults, math anxiety is distinct from other types of anxiety such as test and general anxiety, is more strongly related to math achievement than these other anxieties, and is more predictive of math achievement than of IQ or verbal achievement (Dew & Galassi, 1983; Hembree, 1990; Malanchini et al., 2017). Additionally, the brain activity of adults with high math anxiety differs in ways that suggest this anxiety is specific to math. Notably, functional brain imaging studies show that adults with high math anxiety have greater activity in brain regions associated with experiencing pain when they anticipate doing math activities but not when they anticipate doing reading activities (Lyons & Beilock, 2012).

The negative relation between math anxiety and math achievement exists across the globe, as indicated by data from the Program for International School Assessment (PISA), which assesses academic achievement of 15-year-olds (Foley et al., 2017; J. Lee, 2009). In general, students in higher achieving countries have lower levels of math anxiety. However, students in Asian countries have higher math anxiety than expected given their high math achievement (Foley et al., 2017; J. Lee, 2009; Stankov, 2010). But even within Asian countries, students with higher math anxiety have lower levels of math achievement. Thus, cultural context may play a role in levels of math anxiety but does not disrupt its relationship to math achievement.

Recently, math anxiety and its relation to math achievement has been explored in young children in various cultural contexts. We discuss details of these findings in the following sections. Understanding when math anxiety emerges, whether certain components emerge earlier than others, the factors that influence children's math anxiety, and how it relates to young children's math achievement can inform strategies to address math anxiety or prevent it from emerging in the first place. To preview, math anxiety appears to emerge by early elementary school, tends to be higher in girls, and is predicted by achievement in math by 1st grade. Although math anxiety also predicts math achievement in early elementary school, this relation is not as strong as the math achievement to math anxiety relation. Further, parents' math anxiety and math behaviors play an important role in both children's math achievement and math anxiety.

Development of math anxiety

Emergence and Developmental Changes in Magnitude. In line with findings in adults, factor analyses show that in 8-year-olds, math anxiety is distinct from test and general anxiety (Carey et al., 2017). Moreover, as early as 1st grade, some children report high levels of math anxiety, and this is the case for studies carried out in the U.S. and other countries, including China, Netherlands, and

Germany (Ching et al., 2020; Erturan & Jansen, 2015; Gunderson, Park, et al., 2018; Harari et al., 2013; Jameson, 2013; Krinzinger et al., 2009; Pantoja et al., 2020; Ramirez et al., 2013, 2016; Vukovic et al., 2013; Wu et al., 2012, 2014).

Although math anxiety emerges early, it is higher in older than younger students. However, the increase in math anxiety over development is not linear. In a meta-analysis, math anxiety increased from middle to high school, peaking in 9th and 10th grade, and leveling off in the later years of high school and in college (Hembree, 1990). In other words, students' math anxiety increases between the important transition from middle to high school, in line with research suggesting that the transition to high school leads to more negative math attitudes (Wigfield et al., 1991). Further, Hembree's (1990) findings suggest that math anxiety becomes more stable—and perhaps more difficult to change—in high school.

In contrast to findings showing that math anxiety increases over development, some studies find that math anxiety decreases during the early elementary school years (Gunderson, Park, et al., 2018; Sorvo et al., 2019). However, these findings are difficult to interpret because math anxiety questionnaires for young children typically include items asking about anxiety when given *specific* math problems (e.g., solving 27 + 15) and items asking about *general* math situations (e.g., learning something new in math). Because children learn more math as they progress in school, their math anxiety about solving *specific* math problems may decrease whereas responses to *general* math situations may be more stable. An important next step involves longitudinal studies, starting at a young age, examining how math anxiety develops and changes, using comparable math anxiety measures for younger and older children. For example, future studies could use specific items that are of comparable difficulty for different grade levels, use only general questions about math situations, and/or use physiological measures of math anxiety (Young et al., 2012).

Relation to Math Achievement. Math anxiety is associated with lower math achievement as early as 1st grade in the U.S. and other countries, including China and Germany (Ching et al., 2020; Erturan & Jansen, 2015; Gunderson, Park, et al., 2018; Harari et al., 2013; Jameson, 2013; Pantoja et al., 2020; Ramirez et al., 2013; 2016; Vukovic et al., 2013; Wu et al., 2012, 2014). Further, math anxiety in 1st grade predicts math achievement through at least 3rd grade, over and above children's linear number line estimation, an important foundational math skill (Pantoja et al., 2020). Since these findings are correlational, an important question concerns causality, a topic we return to.

Developmental Changes in the Strength of the Relation. Overall, evidence suggests that the relation of math anxiety to math achievement is stronger in older than younger students. One meta-analysis found no significant difference in the strength of the relation in 5th graders and above compared to 4th graders and below (Namkung et al., 2019). Other meta-analyses, however, found a stronger relation in high school students than in elementary school or middle school students (Barroso et al., 2020; Zhang et al., 2019). In contrast to the pattern of a stronger math anxiety * math achievement relation in older students, Barroso et al. (2020) found the relation was stronger in middle and high school students compared to post-secondary students ($r = -0.24$), a finding the authors posit could be explained by students with lower math anxiety being more likely to continue post-secondary schooling. In sum, the relation of math anxiety to math achievement is generally stronger in older than younger students, but perhaps weaker in college students than middle and high school students due to the selectivity of college students.

Direction of the Relation and Mechanisms Involved. Understanding the direction of the relation of math anxiety and math achievement and whether it changes across development could inform decisions on when and how to address math anxiety. Exactly why the link between math anxiety and math achievement emerges is an open question. On the one hand, high math anxiety might harm math achievement. On the other hand, low math achievement might increase math anxiety. Of course, the relation may be reciprocal from the start and emerge due to other factors, for example, both low math achievement and math anxiety could emerge due to other negative math attitudes or negative attitudes about learning. To begin to understand how this relation emerges in young children, we consider theories that were developed to explain the relation of math anxiety with math achievement over time. There are three prevalent theories on the direction of the relation: Deficit Theory, Cognitive Interference Theory, and Reciprocal Theory. These different theories have been proposed to explain the math anxiety * math achievement relation.

Deficit Theory. According to the Deficit Theory, poor math achievement and negative memories of math lead to higher math anxiety (e.g., Carey et al., 2016; Ramirez, Shaw, & Maloney, 2018). In other words, according to the Deficit Theory, math anxiety is caused by poor math achievement in school and weak foundational math skills over many years. Evidence in support of the Deficit Theory comes from concurrent data on adults, as well as longitudinal data on adolescents and young children. Adults' math anxiety has been found to concurrently relate to basic numerical processing skills, such as counting objects and identifying the larger of two single digit numbers (Dietrich et al., 2015; Maloney et al., 2010, 2011). Maloney and colleagues suggest that math anxiety in adults may result from deficits in basic numerical processing skills that could lead to difficulty developing more advanced math skills as well as to math anxiety.

In a longitudinal study of adolescents in 7th through 12th graders, early math achievement consistently predicted later math anxiety, while the reverse relation was much weaker, and only significant from 7th to 8th grade, and from 8th to 9th grade (Ma & Xu, 2004). Similar findings are reported in studies across one school year with adolescents in the U.S. and Italy, and in young children in China (Ching et al., 2020; Geary et al., 2019; Wang et al., 2020). Other studies supporting the Deficit Theory involve children with learning disabilities (see Carey et al., 2016). However, not all students who struggle with math develop math anxiety (Devine et al., 2017)

Cognitive Interference Theory. The Cognitive Interference Theory posits that math anxiety negatively affects math achievement before, during and after participating in a math-related activity. In other words, math anxiety influences math achievement through a) anticipation of engaging in math, b) disruption of working memory resources both during and after engaging in math, and c) avoidance of engaging in math (e.g., Carey et al., 2016). Evidence supporting this theory has come from experimental studies, as well as concurrent and longitudinal studies of young children, adolescents and adults. Interventions, reviewed in a later section, have decreased the negative effect of math anxiety on math achievement, and improved math achievement in adolescents and adults with high math anxiety, suggesting that high math anxiety causes low math achievement (Jamieson et al., 2010; 2016; Park et al., 2014; Ramirez & Beilock, 2011).

Three mechanisms have been proposed as explanations of how math anxiety negatively affects math achievement: anticipation, working memory, and avoidance. Anticipation of doing math has been found to play a role in the math anxiety * math achievement relation in 7-year-olds as well as adults (Lyons & Beilock, 2012; Young et al., 2012). In other words, when individuals with high math anxiety are given time to worry and think about an upcoming math task, these ruminations disrupt working memory resources and negatively affect math performance.

Working memory has been found to moderate how math anxiety affects math achievement. Paradoxically, children and adults who are arguably more likely to excel in math through high working memory resources, are more likely to have their math achievement suffer if they have high math anxiety. For example, 1st and 2nd grade children's math anxiety and math achievement were related if they had higher working memory, but not if they had lower working memory (Ramirez et al., 2016). Similar results have been found with adults and young children in the U.S. and China, suggesting that across development and cultural contexts, math anxiety is particularly harmful for those with higher working memory (Beilock & Carr, 2005; Ching, 2017; Vukovic et al., 2013). Further implicating working memory in the math anxiety * math achievement relation, a meta-analysis showed that math anxiety is more strongly related to achievement on complex math tasks, which tend to require higher working memory resources than foundational math tasks (Namkung et al., 2019). Thus, working memory, as well as the working memory demands of math tasks, appear to play a role in the math anxiety * math achievement relation in both children and adults.

Further, children with high working memory and high math anxiety are more likely to use less efficient math strategies than their peers with high working memory and low math anxiety (Ramirez et al., 2016). Ramirez et al. (2016) proposed two explanations for this finding. On the one hand, math anxiety may deplete the working memory resources that are needed to use sophisticated and efficient strategies. On the other hand, high math anxiety might alter the behavior of children with high working memory, such that they avoid using sophisticated strategies (Beilock et al., 2017; Ramirez et al., 2016). The latter explanation aligns with findings involving adolescents and adults discussed below.

Avoidance of important math-related situations such as enrolling in math courses and doing challenging math, is another mechanism that has been posited to explain how math anxiety negatively affects math achievement. For example, math anxiety predicts adults' avoidance of challenging math problems even though they have a higher monetary reward than easier math problems, and when the difficulty of the problems has been adjusted for individual differences in math ability (Choe et al., 2019). Choe et al. (2019) suggest that individuals with high math anxiety might believe that the costs of engaging in challenging math situations outweigh the benefits.

Math anxiety appears to predict math avoidance even within math situations that cannot be avoided altogether. For example, high school students' math anxiety predicts the quality of their math behavior, such that those with higher math anxiety report spending less time completing practice problems while studying for a math exam, a study strategy that is more effortful than other strategies (e.g., reviewing solved problems in a textbook; Jenifer et al., under review). Together, these findings suggest that math anxiety might influence both the quantity and quality of math behaviors in adolescents and adults. While less is known about the relation of math anxiety and math avoidance in young children, some 10-year-old children show math avoidance, specifically avoidance of completing arithmetic problems (Chinn, 2012). Whether this math avoidance relates to young children's math anxiety is unclear. Examining the role that math anxiety plays in young children's math-related behaviors could provide insight into how math anxiety influences or is influenced by early engagement in math both in the classroom and at home.

Reciprocal Theory. In contrast to the Deficit Theory, which posits a unidirectional relation of achievement to anxiety and the Cognitive Interference Theory, which posits a unidirectional relation of anxiety to achievement, Reciprocal Theory posits the relation to be reciprocal, such that math anxiety and math achievement influence each other (Ashcraft et al., 2007; Carey et al., 2016). As in the Deficit Theory and the Cognitive Interference Theory, working memory and math avoidance are thought to play a role in the Reciprocal Theory. Ashcraft et al. (2007) suggest that math anxiety could develop from deficits in math skills, and this anxiety could in turn cause further deficits in math achievement through math avoidance and by depleting working memory resources.

In support of the Reciprocal Theory, a meta-analysis of students below 5th grade, and students in 5th to 12th grade, showed the longitudinal relation of early math anxiety to later math achievement was as strong as the reverse relation ($r = -0.37$; Namkung et al., 2019). However, Namkung et al., (2019) did not examine whether the longitudinal relation of math anxiety and math achievement differed for younger and older students. Thus we turn to individual studies examining the longitudinal relation in young children. Gunderson, Park, et al. (2018) assessed 1st and 2nd graders' math anxiety and math achievement at the beginning and end of the school year. Math anxiety at the beginning of the school year predicted math achievement at the end of the school year ($\beta = -0.06$). However, the reverse relation was more than three times stronger ($\beta = -0.20$). Studying 1st graders in China, Ching et al. (2020) also found a stronger relation from math achievement to math anxiety than the reverse. However, Ching et al. (2020) found that the relation of math anxiety to math achievement was not significant. Similarly, Cargnelutti et al. (2017), found the relation of early math achievement to later math anxiety (which was marginally significant; $\beta = -0.19$, $p = .08$) to be stronger than the reverse relation in 2nd graders in Italy. However, in 3rd graders the relation of math anxiety to math achievement was stronger than the reverse, suggesting that the direction of the math anxiety * math achievement relation may change across development. In other words, low math achievement may initially lead to high math anxiety, which then lowers math achievement.

Conclusions. Math anxiety is present and negatively related to math achievement by 1st grade, but higher and more strongly related to math achievement in middle and high school. Thus, addressing the math anxiety * math achievement link may be more successful with young children, before math achievement and math-related behaviors have been compromised over many years perhaps through the establishment of a negative reciprocal relation between math achievement and math anxiety. The math-achievement * math anxiety link might emerge from low math achievement and negative math experiences that lead to math anxiety, but over time this relation may become reciprocal (see Fig. 1). Thus, variations in the quantity and quality of early math experiences may play a role in increasing young children's math anxiety. Longitudinal studies are needed to better understand how the direction of the math anxiety * math achievement relation might change across development. Perhaps changes in school environments as children get older (e.g., more feedback, evaluations, tracking, and comparisons to peers) play a role in the reciprocal relation of math anxiety and math achievement found in adolescents.

We also need more information about how children interpret their early math achievement-related experiences, as well as how key socializers might alter their behaviors based on children's math achievement. Further, research could examine how the math anxiety of children and their key socializers affect children's math-related experiences at home and in the classroom. Understanding whether children's math anxiety alters—or is altered by—their math-related experiences, could help explain the emergence of the math anxiety * math achievement link and inform strategies to break this link.

Gender differences in math anxiety

Emergence and Changes Across Development. Math anxiety is higher in girls than boys by 5th grade, as well as during middle school, high school and college in the U.S. and various countries across the world (A. Devine et al., 2012; Else-Quest et al., 2010; Frenzel et al., 2007; Geary et al., 2019; Hembree, 1990; Hill et al., 2016; Huang et al., 2019; Kyttälä & Björn, 2010; Liu, 2009; Pekrun et al., 2017; Satake & Amato, 1995; Stoet et al., 2016; Todor, 2014; Wigfield & Meece, 1988). However, gender differences are typically small (e.g., $d = 0.23$ to 0.28; Stoet et al., 2016) and there is no evidence that they increase between middle school and college, although we cannot rule out the possibility that students attending college have lower math anxiety than peers who do not attend college. Somewhat counter-intuitively, the difference between adolescent boys' and girls' math anxiety is greater in countries with more gender equality (Else-Quest et al., 2010; Stoet et al., 2016). This could be due to more interaction between boys and girls in countries with more gender equality, leading to more between-group comparisons and opportunities for math-gender stereotypes to negatively affect girls' math anxiety (Stoet et al., 2016; see math-gender stereotypes section).

In contrast to findings showing higher math anxiety in girls by 5th grade, younger children generally do not show a gender difference (Ching, 2017; Dowker et al., 2012; Erturan & Jansen, 2015; Harari et al., 2013; Jameson, 2014; Ramirez et al., 2013). However, a few studies do find small gender differences in early elementary school and when a difference is found, girls show more math anxiety than boys. This pattern has been reported in the U.S., and various countries, including China, Finland, and Italy, at the end but not the beginning of 1st grade, as well as in 2nd to 5th graders, suggesting that the gender difference in math anxiety emerges after children experience a few years of elementary school (Ching et al., 2020; Gunderson, Park, et al., 2018; Hill et al., 2016; Sorvo et al., 2017; Yüksel-Şahin, 2008).

Inconsistent findings with young children regarding gender differences are unlikely due to the use of measures that assess different components of math anxiety, as studies reporting significant and non-significant gender differences often use the same measures. Nonetheless, researchers have suggested that using global measures of math anxiety rather than measures of particular components of math anxiety might obscure gender differences (Geary et al., 2019). Another viable explanation is that many studies of young children may have insufficient power to detect significant gender differences in math anxiety, which are typically small in young children (e.g., $d = -0.17$; Gunderson, Park, et al., 2018).

The Role of Other Math Attitudes, Spatial Skills and Math Avoidance. Researchers have hypothesized that the gender difference in math anxiety could be explained by math-gender stereotypes (Beilock et al., 2007). Additionally, a gender difference in spatial anxiety may play a role in the gender difference in math anxiety. For example, girls in 1st and 2nd have higher spatial anxiety than boys, and a study with college students in Canada found that spatial anxiety uniquely predicted the gender difference in math anxiety (Ramirez et al., 2012; Sokolowski et al., 2019). Further, spatial skills, specifically mental transformation skills, have been shown to predict math skills (Cheng & Mix, 2014; Gunderson, Ramirez, Beilock et al., 2012; Mix et al., 2020), and girls' lower spatial transformation skills (e.g., Levine et al., 1999) may contribute to their math anxiety. Another possibility is that females avoid math more than males, and that this increases their math anxiety (Jenifer et al., in preparation). In sum, the gender difference in math anxiety (favoring boys) may be related to math-gender stereotypes, differences in spatial anxiety, difference in spatial skills, and/or to math avoidance.

Gender Differences in the Strength of the Math Anxiety * Math Achievement Relation. Results have been inconsistent regarding whether the strength of the math anxiety * math achievement relation differs by gender. Some meta-analyses have found no significant gender differences in the strength of the relation in individuals ranging from elementary school to adulthood (Barroso et al., 2020; Ma, 1999; Zhang et al., 2019). However, one meta-analysis found that the relation was stronger in high school boys than girls, suggesting that high math anxiety may be particularly detrimental to boys' math achievement (Hembree, 1990). In contrast, other studies of young children and adolescents the U.S., U.K., and Netherlands have found the relation to be stronger in girls than boys (A. Devine et al., 2012; Erturan & Jansen, 2015; Geary et al., 2019; Schleepen & Van Mier, 2016; Van Mier et al., 2019). Similarly, a study of high achieving high school students showed girls'—but not boys'—math anxiety to be concurrently significantly related to interests in pursuing math or science careers (Huang et al., 2019). It is possible that math-gender stereotypes explain findings of a stronger relation of math anxiety to math outcomes in girls than boys.

Conclusions. Gender differences in math anxiety have typically been examined in older students and adults, finding that females are more math anxious than males. However, there is growing evidence that this gender difference emerges much earlier, by the end of 1st grade. Math-gender stereotypes, spatial anxiety and skills, and math avoidance may play a role in gender differences in math anxiety. Currently, we have no information about whether different factors play a role in the gender difference at different ages.

Further, findings of gender differences in the strength of the math anxiety * math achievement relation are contradictory. Future work could examine whether inconsistencies in findings may be due to differences in age, culture, the math anxiety or achievement measures used, or the components of math anxiety assessed.

Key socializers

Parents' Math Anxiety. Parents' math anxiety predicts young children's and adolescents' math achievement in families from various backgrounds as shown by studies carried out in the U.S., Chile, and India (Berkowitz et al., 2015; Casad et al., 2015; del Río et al., 2020; Schaeffer et al., 2018; Soni & Kumari, 2017). Additionally, Casad et al. (2015) found that parents' and adolescents' math anxiety interact, such that when parents and adolescents both had high math anxiety, adolescents' math achievement was typically lower, and this relation was stronger in same-gender dyads, particularly mother-daughter dyads, consistent with findings that same-gender role models have a strong effect on girls' STEM interests (see Math-Gender Stereotype section).

Further, parents' math anxiety predicts adolescents' math anxiety (Casad et al., 2015; Soni & Kumari, 2017), but we do not know whether this is the case for young children. In addition to examining whether parents' math anxiety predicts young children's math anxiety, future work could examine whether certain components of parents' math anxiety are linked to children's math attitudes and achievement. For instance, it is possible that the affective component of parents' math anxiety (which involves emotions of nervousness and tension around math) is more predictive of children's math achievement and math anxiety than the cognitive component of parents' math anxiety (which involves worrying about one's math performance). It is also possible that the association between particular components of parents' math anxiety and children's math achievement and math attitudes changes over development. Indeed, developmental research is needed to understand the role of particular components of parents' math anxiety on children's math anxiety and achievement.

There is evidence that parents' math anxiety predicts the degree to which young children identify with math (del Río et al., 2020), which is likely associated with children's math anxiety. Further, other math attitudes parents hold may influence their children's math anxiety. Notably, parents' expectations of their 2nd grade children's math achievement predicted their children's math anxiety, as well as their math achievement (Vukovic et al., 2013). We next consider the mechanisms through which parents' math anxiety could influence their children's math attitudes and math achievement.

Mechanisms. The quantity and quality of parents' math input may explain why parents' math anxiety predicts children's math attitudes and math achievement (see Fig. 1). Given the link between adults' math anxiety and math avoidance, it is not surprising that parents' math anxiety predicts their math input. For example, in a study of families in Chile from low socioeconomic status (SES) backgrounds, parents' math anxiety predicted the quantity of the math input they provided to their preschoolers (del Río et al., 2017). Parents' math anxiety is even associated with the math input they provide children well before their children start school. Parents with higher math anxiety have been shown to engage in less talk about number and qualitatively different types of number talk with their 14- to 30-month-old toddlers than parents with lower math anxiety (Berkowitz et al., 2021). Specifically, parents with higher math anxiety labeled set sizes less frequently (e.g., "You have three blocks") but did not differ in the frequency of counting. However, there was an interaction of parent math anxiety and family SES, such that parents' math anxiety predicted number talk for families from higher SES but not lower SES backgrounds. For families from higher SES backgrounds, parents with high math anxiety talked less about number but for families from lower SES backgrounds, parents' number talk was infrequent regardless of their math anxiety. Together, these findings highlight the importance of examining parent–child math interactions for families who differ with respect to parent math anxiety and SES background.

Further, the relation of parents' math anxiety to math interactions with their children may depend on the nature of the math activity. In support of this view, parents' math anxiety does not significantly predict how frequently they help their children with math homework (DiStefano et al., 2020; Maloney et al., 2015). However, compared to parents with low math anxiety, parents with high math anxiety may less frequently engage their children in math interactions around play and daily routines, which are more optional than homework. Nonetheless. parents with different levels of math anxiety may differ in the quality of their homework help.

In support of this possibility, when parents reported high math anxiety and frequently helping their 1st and 2nd graders with math homework, the quantity of their homework help negatively predicted their children's math anxiety and math learning (Maloney et al., 2015). Thus, the frequent and well-meaning homework help of parents with high math anxiety may backfire (Maloney et al., 2015). Consistent with this view, DiStefano et al. (2020) found that highly math anxious parents of 1st through 6th graders reported that math homework interactions were a negative experience for them, suggesting that the quality of these interactions may suffer if parents have high math anxiety. Consistent with this possibility, in an observational study of parents and their young children using a low-pressure math app with story problems and answers provided, parents' math anxiety predicted the quality of their math interactions (e.g., respecting children's prior knowledge and promoting critical thinking; Herts et al., 2019). Together, these findings suggest that parents' math anxiety predicts the quantity and quality of their early parent–child math interactions, but this relation may differ for families from lower and higher SES backgrounds and for different kinds of math interactions— notably math homework and math activities unrelated to homework. Nonetheless, differences in the quantity and quality of parent–child math interactions may explain why parents' math anxiety predicts their children's math anxiety and math achievement.

Teachers' Math Anxiety. Young children likely have had a teacher with high math anxiety, as college students majoring in elementary school education tend to have higher math anxiety than those with other majors (Hembree, 1990). Negative relations between teachers' math anxiety and children's math learning have been found as early as 1st and 2nd grade boys and girls from diverse SES backgrounds in the U.S. and Belize (Richland et al., 2020; Schaeffer et al., 2020) as well as for high school students (Ramirez, Hooper, et al., 2018). However, this negative relation may not emerge before children begin formal schooling. A study with preschool teachers and their students in Germany, found that teachers' math anxiety did not significantly predict their students' math achievement, suggesting that the relation of teachers' math anxiety and children's math learning may arise after preschool (Jenßen et al., 2020). This could be because relatively little time is spent on math in preschool classrooms, as in the U.S. math takes up only 3% of total class time while reading takes up 11% of class time (Fuhs et al., 2012).

Mechanisms. Teachers' math anxiety may be associated with other negative math attitudes they hold. For example, pre-service and in-service elementary school teachers with higher math anxiety are less confident in teaching math (Bursal & Paznokas, 2006; Gresham, 2008; Richland et al., 2020; Swars et al., 2006). In other words, teachers with higher math anxiety believe they are less capable of being effective math teachers. This finding raises the possibility that the relation of teachers' math anxiety to their students' higher math anxiety and lower math achievement could be explained by teachers' low confidence in their ability to teach math effectively or to actual differences in the quality of their teaching.

Students are likely picking up on negative math attitudes their teachers may hold. Ramirez, Hooper, et al. (2018) found the relation of high school teachers' math anxiety to students' math learning was partially mediated by how much students perceived their teacher to believe that not everyone can be good at math (i.e., a fixed mindset about math). Thus, teachers with high math anxiety may convey other maladaptive math attitudes to their students, which then harms children's math achievement (see Mindset/Implicit Theory section). Additional support for this view comes from a study showing that girls in 1st and 2nd grades had lower math achievement at the end of the school year, controlling for their math achievement at the beginning of the school year, if their female teachers had higher math anxiety, and this relation was mediated by girls' endorsement of the stereotype that boys are better at math than girls (Beilock et al., 2010). Together, these findings highlight the importance of examining how teachers' math anxiety influences the quality of their teaching and the math-related messages they convey, which may in turn influence students' math achievement and math attitudes.

Conclusions. Key socializers' math anxiety predicts children's math anxiety and math achievement, perhaps because their math anxiety predicts the quantity and quality of the math interactions they have with children, their confidence in teaching or supporting children's math learning, and the messages they convey to children about math (see Fig. 1). However, these relations should be further examined in families from diverse SES backgrounds. Various questions remain. First, we need to increase our understanding of the causal relations between key socializers' math anxiety and the quality of their math teaching, which is essential for developing interventions. Second, we need more information about key socializers' anxiety about engaging in math with children as well as their general math anxiety, as there may be differences in these anxieties, and the former may be more consequential for children's math attitudes and math achievement. Third, we need to assess whether teachers' and/or parents' math attitudes play a particularly important role in children's math anxiety and math achievement at certain ages. Finally, it is important to further examine how the math anxiety of same-gender versus opposite-gender key socializers contribute to children's math attitudes and math achievement, and how the math anxiety of parents and teachers jointly affect children's math learning and attitudes.

Interventions

Adolescents and Adults. Interventions with adolescents and adults have reduced the negative effect of math anxiety on math achievement in the short-term through expressive writing, reappraisal, and focused breathing. Writing interventions involve having participants write out their thoughts and feelings about an upcoming math exam. This has been found to free up working memory resources that would otherwise have been compromised (Park et al., 2014; Ramirez & Beilock, 2011). In reappraisal interventions, individuals are taught to reinterpret signs of anxiety and arousal as beneficial rather than harmful to achievement (Jamieson et al., 2010; 2016). Further, a focused breathing exercise increased calmness prior to a math test (Brunyé et al., 2013). Together, these findings suggest that the link between math anxiety and math achievement can be reduced in adolescents and adults—at least in the short-term—by externalizing worries through writing, reinterpreting signs of anxiety, and increasing calmness.

Young Children. A cautionary note is that interventions that benefit older students with high math anxiety may not have the same positive effects for young children. For example, rather than improving math achievement, writing out worries appears to harm children's math achievement. This was shown in a study of 10- to 12-year-old children who completed a math pretest and were then prompted to either write down their worries about an upcoming math lesson and test (intervention condition) or copy an emotionally neutral paragraph (control condition; Mesghina & Richland, 2020). Then, students watched a videotaped math lesson and took a math post-test. The writing intervention decreased math learning, an effect that was mediated by feeling more pressure to do well on the math test. The writing intervention was particularly harmful for girls that had higher working memory and higher math achievement at pretest. In other words, while writing interventions have been found to free up working memory resources necessary for an upcoming math task in adolescents and adults, this type of intervention was detrimental for younger children, possibly because of the increased pressure they felt after writing depleted their working memory resources.

An intervention that has been successful in reducing young children's math anxiety involves increasing their math learning experiences. Indeed, Supekar et al. (2015) found that for 3rd grade children with high math anxiety, intensive math tutoring administered individually over 8 weeks normalized activity levels in brain regions important for emotion regulation and math cognition. In turn, this reduced children's math anxiety and increased their math learning. To our knowledge, this is the only intervention that successfully reduced young children's math anxiety, and it did so by improving children's math skills.

Parents and Their Children. One intervention eliminated the link between parents' math anxiety and elementary school children's math achievement by encouraging positive math interactions through a structured math activity. Parents and their 1st grade children were provided with a math app that guided low-pressure math interactions through fun daily passages and math-related questions and answers (Berkowitz et al., 2015). The intervention eliminated the negative relation between parents' math anxiety and children's math learning through 3rd grade (Schaeffer et al., 2018). Thus, increasing fun and low-pressure math learning opportunities at home could break the link between parents' higher math anxiety and children's lower math achievement.

Conclusions. While interventions that externalize anxiety through writing mitigate the negative relation of math anxiety to math achievement in adolescents and adults, this approach may harm young children's math achievement. Thus, examining whether interventions that have been successful with adolescents and adults are also successful with young children is essential. With young children, a more effective way to break the link between children's—or parents'—math anxiety with children's math achievement may be for children to learn more math in school and engage in fun and low-pressure math learning activities with their parents. Together, these findings suggest that cognitive interventions may be more effective for younger children, whereas affective interventions may be more effective for adolescents and adults. More work is needed to understand whether reappraisal or focused-breathing interventions that have been effective for adolescents and adults with high math anxiety would also be effective for young children. Additionally, intervening on multiple factors (e.g., cognitive and affective) may be particularly effective, a possibility that is supported by research with adolescents and adults (Jamieson et al., 2018; Yeager et al., 2016).

What we know and questions for future research

By 1st grade, math anxiety is present and negatively related to math achievement. This link may emerge by math achievement-related experiences first influencing math anxiety (see EMAA model, Fig. 1). Potential mechanisms that could explain this link include the classroom environment (e.g., emphasis on performance, and comparisons to peers), and the quantity and quality of math interactions at home. To better understand how young children's math achievement-related experiences might influence their math anxiety and vice versa, more work observing and examining children's math interactions with key socializers is needed. Additionally, interviewing children with different levels of math anxiety about their low or high math scores would provide valuable information about how they interpret these experiences, and whether these interpretations influence their math anxiety. We discuss children's responses to failure experiences further in the Mindset/Implicit Theory section. Additionally, there may be a genetic component to math anxiety (Wang et al., 2014) that future work could further examine.

Adolescents and adults' math anxiety is associated with their math choices and behaviors. However, it is unclear whether young children's math anxiety is associated with the quantity and quality of their math-related behaviors. To understand whether math anxiety influences—or is influenced by—young children's math-related behaviors, future work could observe the quantity and quality of behaviors within math situations at home and at school (e.g., engagement and math avoidance).

Girls have higher math anxiety than boys by 5th grade, and perhaps as early as the end of 1st grade, suggesting that math-gender stereotypes might play a role in children's—particularly girls'—math anxiety. Math anxiety is also related to math self-concept and mindset. We discuss these relations and implications in more detail in those sections, but one take-away is that it is important to understand how these math attitudes emerge and develop in young children and how they may be influencing each other and math achievement.

Key socializers' math anxiety plays an important role in children's math anxiety and math achievement, likely due to less frequent and lower quality math interactions with key socializers who are highly math anxious. Further, math anxiety may influence other important math attitudes key socializers hold, a topic we return to in the Math Self-Concept section. Finally, the effectiveness of different types of interventions at different developmental time points needs investigation. Notably, there is some indication that affective interventions that have been effective for adolescents and adults may not be effective for young children. However, increased exposure to math—at school and at home—appears to decrease young children's math anxiety and improve their math achievement.

Math self-concept

Influential theories proposed by Eccles, Wigfield, Marsh, and colleagues posit that one's self-perception of competence in a domain plays an important role in achievement in that domain (Eccles et al., 1993; Marsh, 1990). Self-concept refers to one's self-perception or beliefs about their *current* competence in a particular domain, such as math (e.g., "How good are you at math?"; Eccles et al., 1993; Eccles & Wigfield, 2002). Domain-specific self-concept is posited to be a construct theoretically separate from *expectations* of future achievement (e.g., "How good do you think you will do in math this year?"), and from perception of task *difficulty* (e.g., "How hard is math for you?"; Eccles & Wigfield, 2020). However, empirical evidence has not distinguished between self-perceptions of current ability, expectations of future achievement, and task-difficulty suggesting that they are measuring a common underlying construct (Eccles et al., 1993). Thus, researchers typically measure these as one construct, termed "self-concept", and include questions about all three perceptions. In line with findings of math anxiety, math self-concept predicts adolescents' and adults' math achievement, as well as their math-related choices including course-taking and careers (Eccles & Wigfield, 2020; Wigfield & Eccles, 2020).

Understanding what factors influence the development of children's math self-concept, as well as when and why it begins to relate to math achievement can help inform strategies to improve math self-concept and math achievement. To preview, our review shows that some children, particularly girls, begin to have negative perceptions of their math ability by early elementary school. In addition, math achievement predicts math self-concept more strongly than the reverse in early elementary school. Finally, there are intergenerational effects such that parents' child-specific math attitudes predict their young children's math achievement and math self-concept.

Development of math self-concept

Emergence and Developmental Changes in Magnitude. Some researchers find that self-concepts of abilities are domain-specific by preschool and elementary school, but they increase in specificity across the early elementary school years (Dapp & Roebers, 2018; Dweck, 2002; Eccles et al., 1993; Marsh et al., 1991; 1998; 2002; Möller et al., 2009; Wigfield et al., 1997; Valeski & Stipek, 2001). Children's math self-concept generally becomes more stable over the elementary school years and declines in higher grades (Fredricks & Eccles, 2002; Jacobs et al., 2002; Markovits & Forgasz, 2017; Upadyaya & Eccles, 2015; Weidinger et al., 2018; Wigfield et al., 1997). This decline is thought to reflect children's increasing accuracy in perceiving their ability level, their increasing pessimism about their achievement, and changes in their school environment (e.g., higher pressure, and more comparisons and evaluations at higher grade levels; Dweck, 2002; Eccles et al., 1993; Fredricks & Eccles, 2002; Jacobs et al., 2002). In contrast to this general decline, some studies find there is a small increase in math self-concept from kindergarten to 1st grade (Dapp & Roebers, 2018; Valeski & Stipek, 2001). It is possible that this early increase is due to the nature of the measures that are used. We discuss differences between measures in a section below.

Superimposed on these general age trends, there are individual differences in how math self-concept changes across development. In a longitudinal study of children from 4th grade through college, about 40% of individuals maintained a relatively high math self-concept, 40% began with moderate levels that declined over time, and 20% began with moderate levels with a steeper decline over time (Musu-Gillette et al., 2015). Importantly, trajectories of change in math self-concept predicted future choices of college majors, controlling for initial math achievement. Those that maintained a relatively high math self-concept were more likely to have math-intensive college majors. Thus, starting with and maintaining a high math self-concept may be particularly important for future math-related choices.

Researchers have begun to take person-centered approaches in which the pattern of students' low, medium, or high math self-concept and math task-value (i.e., how valuable one thinks math is for them) are considered together. Lazarides et al. (2020) found four profiles in 7th to 12th grade students: high, medium, and low math self-concept and math task-value, with levels matching across these measures and another profile consisting of medium to high math self-concept and high math attainment-value (i.e., personal importance of a task; a component of math task-value) but low math intrinsic-value (i.e., expected enjoyment; another component of math task-value). These patterns remained stable over time, and predicted math-related career plans, college majors, and actual careers in adulthood. For example, students with medium to high math self-concept and math attainment-value but low math intrinsic-value, were less likely to major in math-related fields and to have math-related careers in adulthood than students with consistently high motivational profiles.

Similar findings were reported by Lazarides et al. (2019) with high school students in Germany. Additionally, boys were over-represented in the high motivation profile and girls were over-represented in the low motivation profile (Lazarides et al., 2019). An important take-away from these studies is that adolescents sometimes hold differing levels of math self-concept and math task-value. Examining combinations of math self-concept, task value, and other math attitudes in young children, and how these combinations relate to their math achievement and career paths is an important direction for future research, as it will inform our understanding of whether young children might also hold varying levels of different math attitudes.

Relation to Math Achievement. Math self-concept has been reported to be moderately related to math achievement by 3rd grade in various studies in the U.S., Belgium, and Germany (Arens et al., 2011; Ganley & Lubienski, 2016; Justicia-Galiano et al., 2017; Pinxten et al., 2014; Wigfield et al., 1997). This relation has also been found in children as early as 1st grade (Dapp & Roebers, 2018; Dowker et al., 2019; Herbert & Stipek, 2005; Valeski & Stipek, 2001), and in children as young as 6 years old in Germany, prior to the start of formal schooling (Arens et al., 2016; Marsh et al., 2002). Some studies that include both kindergarteners and 1st graders have found math self-concept and math achievement to be significantly related in 1st grade but not in kindergarten (Dapp & Roebers, 2018; Valeski & Stipek, 2001). In addition to its relation to math achievement, math self-concept has been found to positively relate to the quality of 1st graders' overall engagement in school, and to negatively relate to 4th to 7th graders' perception of the effort they put into math (Pinxten et al., 2014; Valeski & Stipek, 2001).

As we will discuss in the *Direction of the Relation* section, there is evidence that in young children math achievement influences math self-concept, and that the relation becomes reciprocal in adolescents. Before discussing the direction of the math self-concept * math achievement relation, we consider whether the type of measure used to assess math self-concept may play a role in developmental differences in math self-concept and its relation to math achievement.

Differences in Measures of Young Children's Math Self-Concept. Three main types of measures of math self-concept have been used with children, in part related to different theories about math self-concept, a discussion that is outside the scope of this review (see Wigfield & Eccles, 2000). The most common measure involves questions about *general* math ability (e.g., how good are you at/how well will you do in math?), as well as questions about how good children think they are at math compared to other school subjects, how good they think they are at math compared to their peers, and how difficult math is for them. The comparison questions are important, as math self-concept is posited to be formed in part through *external* comparisons to others, and in part through *internal* comparisons to one's abilities in other domains (Marsh, 1986; 1990). This type of measure has been commonly used with children as early as 1st grade (Eccles et al., 1993; Marsh, 1990). A similar type of measure also asks children as young as kindergarteners about their general math ability but does not include questions about comparisons to peers or other domains, or about difficulty (Valeski & Stipek, 2001).

A second common math self-concept measure asks children about their *specific* math abilities (e.g., how good are you at counting?) but not about comparisons to peers or other domains, or about difficulty. This type of measure has been used with children before they enter formal schooling, as well as with children in elementary school (Dowker et al., 2019; Marsh et al., 2002). A third type of measure that has been used with kindergarteners and 1st graders asks them about their ability in *specific* math activities compared to their peers

(Dapp & Roebers, 2018). In this measure, children are shown a set of stick figures representing their classmates ordered from the best to the worst in a specific math activity and asked to point to the one that represents their math ability.

Children's responses to all three of these types of measures have been found to relate to their math achievement (Arens et al., 2011; Dowker et al., 2019; Justicia-Galiano et al., 2017). However, two studies found a significant relation between math self-concept and math achievement in 1st graders but not kindergarteners (Dapp & Roebers, 2018; Valeski & Stipek, 2001), even though their math self-concept measures had high internal reliability in both grades. These studies assessed math self-concept via questions about *general* math ability (but not comparisons to peers or other domains, or difficulty) or their *specific* math activities compared to peers. One possibility is that children's math self-concept becomes more predictive of math achievement with increasing exposure to formal schooling. Additionally, some studies find that young children have difficulty distinguishing between "effort" and "ability" (e.g., Folmer et al., 2008; Nicholls, 1978), although a recent study found that young children can do this when questions are simplified (e.g., Muradoglu & Cimpian, 2020). Nonetheless, it is important to assess young children's conception of "ability" when interpreting developmental changes in the relation to various aspects of math self-concept and math achievement.

An interesting question is whether young children's math self-concept is more influenced by comparison to peers or by comparison to other abilities, or both. Children's different experiences may contribute to their understanding of "ability" and thus to their math self-concept (see Dweck, 2002). For example, being in a kindergarten classroom that emphasizes evaluations and comparisons can result in children having lower perceptions of their general ability—specifically how "smart" they think they are compared to their peers (Stipek & Daniels, 1988). Thus, young children's understanding of ability, and the relation of their math self-concept with their actual math achievement may depend on how much their abilities are compared to others (see Boaler, 2013 for review).

Developmental Changes in the Strength of the Relation and Math Achievement. Like math anxiety, math self-concept is more strongly related to math achievement in older than younger students. A *meta*-analysis found that the strength of the relation increased from elementary to early high school (Ma & Kishor, 1997). The increasing strength of this relation over time raises the question of whether math self-concept affects math achievement, math achievement affects math self-concept, or whether this relation is reciprocal.

Direction of the Relation. The direction of the math self-concept * math achievement relation may change across development. One view is that the math self-concept * math achievement relation is reciprocal (Calsyn & Kenny, 1977; Eccles & Wigfield, 2020; Marsh & Craven, 2006). This view is supported by studies of adolescents in Germany, Belgium and Taiwan that find that math self-concept predicts math achievement as strongly or more strongly than the reverse (Arens et al., 2017; Chen et al., 2013; Marsh et al., 2005; Möller et al., 2011; Pinxten et al., 2014; Sewasew et al., 2018).

Another view is that math achievement influences math self-concept and this view is supported by studies carried out in the U.S. and Germany that included students in preschool and elementary school as well as middle school (Arens et al., 2016; Ganley & Lubienski, 2016; Helmke & van Aken, 1995). For example, in a longitudinal study of 3rd to 8th graders, math achievement predicted math self-concept in both elementary (3rd to 5th grade; $r = 0.27$) and middle school (5th to 8th grade; $r = 0.24$; Ganley & Lubienski, 2016). However, the reverse relation (math self-concept to math achievement) was only marginally significant in middle school ($r = 0.05$) and not significant in elementary school. A similar pattern was found in even younger students, with the math achievement of 5- to 6-year-old preschoolers in Germany significantly predicting their math self-concept, and not the reverse (Arens et al., 2016). These findings suggest that the math self-concept * math achievement relation may be reciprocal in adolescents, but in young children math achievement appears to be more predictive of math self-concept than the reverse.

Supporting the view that the math self-concept * math achievement relation changes across development, a study of 5th to 11th grade students in Taiwan, found that the relation from math self-concept to math achievement increased with age, whereas the relation from math achievement to math self-concept decreased with age (Chen et al., 2013). Further, the math self-concept * math achievement relation may differ for different measures of math achievement (Arens et al., 2020; Helmke & van Aken, 1995). For example, in a study of 6th to 9th grade students in Germany, math test scores predicted math self-concept and not the reverse, but math class grades and math self-concept were reciprocally related (Arens et al., 2020).

In sum, evidence suggests that young children's math achievement more strongly predicts their math self-concept, whereas adolescents' math self-concept is reciprocally related to and perhaps more strongly predicts their math achievement (see Fig. 1). The stronger relation of math achievement to math self-concept than the reverse in young children echoes the finding for math achievement and math anxiety. An important caveat to interpreting these relations, is that the results we have discussed are correlational, and experimental work is needed to determine causal relations. Next, we consider causal mechanisms that could account for the math self-concept * math achievement relations.

Mechanisms Explaining the Relation of Math Self-Concept and Math Achievement. Situated Expectancy-Value Theory (SEVT) posits that math achievement both influences and is influenced by math self-concept (Eccles & Wigfield, 2020). We first discuss mechanisms posited to explain how math self-concept could influence math achievement-related outcomes. According to SEVT, math self-concept (perceptions of *current* math ability) predicts *expectations* of future math achievement, as well as math task-value, which includes the subcomponents of interest (i.e., expected enjoyment of math), attainment (i.e., personal importance of math), utility (i.e., how useful one thinks math is for their future), and cost (i.e., the effort and emotional cost of doing math; Eccles et al., 1993; Wigfield & Eccles, 2000). In turn, math expectations and math task-value are posited to predict math achievement-related outcomes (Wigfield & Eccles, 2020).

Evidence shows that math expectations and math task-value are related, the strength of this relation increases over time, and changes in expectations drive changes in math task-value (see Wigfield & Eccles, 2020). However, as we discussed above, math self-concept (i.e., perception of *current* math ability) is empirically indistinguishable from *expectations* of future math achievement—at least based on existing measures—and measures of math self-concept include questions about both *current* math ability and *expectations* of future math achievement. Therefore, the posited causal pathway from perceptions of current math ability to math expectations and math task-value, to math achievement-related outcomes lacks evidence.

We now turn to mechanisms that could explain the reverse direction of the math achievement * math self-concept relation, the former influencing the latter. SEVT posits that previous math achievement-related experiences influence one's *interpretation* of these experiences, which then influence affective reactions and memories of math, which in turn influence math self-concept (Eccles & Wigfield, 2020). One could think of math anxiety as a type of affective reaction that could mediate the relation of math achievement to math self-concept. Consistent with this view, a study of 15-year-old students in Belgium who took the PISA survey showed a concurrent relation between math self-concept and math achievement, which was mediated by their math anxiety (Ferla et al., 2009). However, experimental studies are needed to determine causal relations. Related to this finding, in the next section we turn to research on the relation of math self-concept to math anxiety.

The Relation of Math Self-Concept and Math Anxiety. Higher math anxiety is associated with lower math self-concept concurrently in 2nd graders, and in adolescents and adults in the U.S., and various countries across the world (Ferla et al., 2009; Jameson, 2014; Justicia-Galiano et al., 2017; Kaskens et al., 2020; Kyttälä & Björn, 2010; J. Lee, 2009; Liu, 2009; Meece et al., 1990; Sokolowski et al., 2019; Wigfield & Meece, 1988). We lack information on the direction of the relation in young children and whether it changes across development.

In contrast to SEVT, which posits that affective reactions to memories of math could influence math self-concept, the Interpretation Account posits that high math anxiety develops not from low math achievement, but from low math self-concept and how one *interprets* their math achievement-related experiences (Ramirez, Shaw, & Maloney, 2018). Supporting this view, in a study of 7th to 9th graders, the relation of math achievement to math anxiety one year later was mediated by math self-concept (Meece et al., 1990). Similarly, in a study of high schoolers in the Netherlands, math self-concept mediated the concurrent relation of math achievement and math anxiety (Van der Beek et al., 2017). This account would gain further support by findings showing that the relation of math anxiety does not mediate the relation between math self-concept and math achievement.

In addition to longitudinal studies finding that adolescents' math self-concept mediates the relation of math achievement to math anxiety (Meece et al., 1990; Van der Beek et al., 2017), the direction of the math anxiety * math self-concept relation has been examined through short-term longitudinal studies of adolescents (Ahmed et al., 2012; Wang et al., 2020). For example, a study of 7th grade students in the Netherlands found the relation to be reciprocal, but the relation of math self-concept to later math anxiety was twice as strong as the reverse (Ahmed et al., 2012). Additionally, a study of high school students in Italy found a reciprocal relation between math anxiety and math self-concept, but this relation was only significant in boys, perhaps because boys with a low math self-concept have difficulty reconciling this with the societal expectation that boys are good at math, which makes them more anxious about math (Wang et al., 2020). Thus, math-gender stereotypes may play a role in the relation of math attitudes to each other, and to differences in these relations in boys and girls.

In sum, these two theories—SEVT and the Interpretation Account—posit that math self-concept and math anxiety are related but disagree about the direction of this relation (see EMAA model, Fig. 1) and the mechanisms underlying this relation. While SEVT posits a relation from affective reactions to math-self-concept—which would suggest that math anxiety influences math self-concept—the Interpretation Account posits that math self-concept influences math anxiety. Clearly, more work is needed to understand the longitudinal and causal relations of math achievement, math self-concept, and math anxiety, but existing work highlights that there are important relations among these constructs. While evidence seems to favor the Interpretation Account in adolescents (Ahmed et al., 2012; Meece et al., 1990; Van der Beek et al., 2017), experimental studies are needed to examine whether improving math self-concept in turn decreases math anxiety, and/or the reverse.

Conclusions. While more experimental work is needed to determine causality, the math self-concept * math achievement link appears to emerge by math achievement first influencing math self-concept. To understand why math achievement might influence math self-concept, it is important to understand how young children interpret their math achievement-related experiences. Perhaps one way to break the link between low math achievement and low math self-concept is to encourage young children to focus on their progress in learning math rather than comparing their math achievement to that of others—in other words, to take a more formative assessment approach to early math learning (e.g., Raudenbush et al., 2020). A greater focus on the process of learning and mastering math rather than performing well in math (a topic we discuss in the Mindset/Implicit Theory section) may be an effective way to break this link.

Further, math anxiety and math self-concept are concurrently related by early elementary school. In adolescents, the relation of math self-concept to math anxiety may be stronger than the reverse, but the direction of this relation in young children and whether it changes across development are open questions. Understanding the development of these attitudes and whether they are causally related would inform intervention approaches aimed at improving these attitudes. Further, we lack information about how math self-concept relates to other math attitudes, particularly in young children.

Gender differences in math self-concept

Emergence and Changes Across Development. Studies in the U.S. and Germany consistently show that the math self-concept * math achievement relation is similar for boys and girls ranging from elementary school to high school (Ganley & Lubienski, 2016; Ma & Kishor, 1997; Marsh et al., 2005; Sewasew et al., 2018). However, boys tend to have a more positive (higher) math self-concept than girls consistent with the finding that boys tend to have lower math anxiety than girls. Next, we discuss the emergence of the gender difference in math self-concept.

Gender differences in self-concept are domain-specific and tend to follow stereotypical patterns, such that girls perceive their ability to be lower in math and sports, but higher in reading and music than boys (Eccles, 1993; Fredricks & Eccles, 2002; Jacobs et al., 2002; Marsh, 1989). Gender differences in math self-concept are consistently reported in 5th grade and above in the U.S. and various countries across the world (Dowker et al., 2012; Else-Quest et al., 2013; Ganley & Lubienski, 2016; Herbert & Stipek, 2005; Jerrim & Schoon, 2014; C.Y. Lee & Kung, 2018; Liu, 2009; Marsh et al., 2005; Markovits & Forgasz, 2017; Möller et al., 2011; Sewasew et al., 2018; Skaalvik & Skaalvik, 2004). It is possible that gender differences in domain-specific self-concept result from gender differences in math and reading achievement—that is individuals' relative strengths influence their self-concepts in particular academic domains. For example, girls tend to perform better than boys in reading (Stoet & Geary, 2018) and have higher reading self-concept than boys but tend to perform worse than boys in math (Stoet & Geary, 2018), and have lower math self-concept than boys.

Whether there are gender differences in math self-concept in early elementary school is unclear. Some studies carried out in the U.S. and Germany have found a small difference in elementary school, favoring boys (Dapp & Roebers, 2018; Eccles, 1993; Jacobs et al., 2002; Marsh et al., 1998, Marsh & Yeung, 1998; Wigfield et al., 1997). In contrast, other studies, carried out in Germany and the U.K, have not found a significant gender difference in math self-concept in preschoolers through 3rd graders (Arens et al., 2016; Dowker et al., 2019; Lohbeck et al., 2017; Marsh et al., 2002). Further, in a longitudinal study of children from low-income and racially diverse backgrounds in the U.S., there were no significant gender differences in kindergarteners' and 1st graders' math self-concept, but 3rd and 5th grade girls had a lower math self-concept than boys (Herbert & Stipek, 2005). Studies consistently find that once gender differences in math self-concept emerge, they do not appear to increase over time (Jacobs et al., 2002; Fredricks & Eccles, 2002; Nagy et al., 2010; Sewasew et al., 2018; Wigfield et al., 1997). Together, these findings show that gender differences in math self-concept are not consistently found until late in elementary school as was the case for math anxiety.

Researchers have hypothesized that cultural context plays a role in whether there are gender differences in math self-concept, as well as when these differences emerge (Nagy et al., 2010; Wigfield et al., 2015). In a meta-analysis of two international datasets, PISA and Trends in International Mathematics and Science Study (TIMSS), 14- to 16-year-old boys across 69 countries reported math self-concepts that were one third of a standard deviation higher than girls' (Else-Quest et al., 2010). Surprisingly, gender differences in math self-concept were larger in countries that had greater gender equity, similar to findings for math anxiety and math-gender stereotypes (see Math Anxiety and Math-Gender Stereotypes sections). In contrast, in a study of 15-year-old students across 23 countries, girls in countries with greater gender diversity in STEM careers reported higher math self-concepts than girls in countries with less gender diversity in STEM, controlling for achievement at the individual and school levels (Niepel et al., 2019). It could be that the measure used by Else-Quest et al. (2010) to determine societal gender equity is not as directly relevant to girls' math self-concept as gender diversity in STEM careers. Thus, while societal gender equity predicts larger gender differences in math self-concept, greater gender diversity in STEM careers predicts smaller gender differences in math self-concept. These findings are informative in terms of showing the kinds of information (e.g., female role models) that could help close the gender gap in math self-concept, and perhaps other math attitudes.

Conclusions. In sum, adolescent girls' math self-concept is lower than boys', even though there is not a gender difference in math achievement. There is some evidence that small mean-level gender differences in math self-concept emerge much earlier, by kindergarten and 1st grade, mirroring findings with math anxiety. Once the gender difference in math self-concept emerges it appears to remain stable. Importantly, the gender difference in math self-concept varies across countries, at least for adolescents, and researchers are beginning to uncover factors that could contribute to these differences.

Key socializers

Parents. According to SEVT, children's math self-concept and math achievement-related outcomes are influenced by their parents' child-specific math beliefs (e.g., their expectations about how well their child will do in math and how valuable they think math is for their child; Eccles & Wigfield, 2020; Wigfield et al., 2006, 2015). Parents' child-specific math beliefs are evident quite early and can have long-term effects on children's math self-concept, math achievement, and career choices. For example, parents' child-specific math beliefs predict children's math self-concept and math achievement as early as 1st grade (Fredricks & Eccles, 2002; Wigfield et al., 1997). The relation of parents' math expectations to their children's math self-concept may become stronger over time, as shown by a study of parents and their 1st to 6th grade children (Wigfield et al., 1997). Further, parents' math expectations moderate the rate and magnitude of the decline in children's math self-concept from elementary to high school and predict children's future career choices (Bleeker & Jacobs, 2004; Wigfield et al., 2006, 2015). Strikingly, parents' child-specific math beliefs predict adolescents' math self-concept more strongly than children's previous math achievement (Jacobs, 1991). It is important to increase our understanding of *how* parents' child-specific math beliefs influence their children's math self-concept and math achievement.

Mechanisms. Parents' child-specific math beliefs predict the activities they engage in with their young children and adolescents (Simpkins et al., 2012; for reviews see Wigfield et al., 2006, 2015; see Fig. 1). In addition, a separate line of research shows that as early as the toddler years, parents' interactions with their children—specifically parents' frequent high quality number talk—predict children's foundational number knowledge (Gunderson & Levine, 2011; Levine et al., 2010; see Fig. 1). Examining how parents' child-specific math beliefs (e.g., their expectations and value of their child's math success) influence the quality of early parent–child math interactions is an important research direction. This approach could enhance our understanding of the mechanisms through which parents' child-specific math beliefs influence children's math achievement-related outcomes.

There is some evidence that parents' math-related behaviors predict their elementary school children's math attitudes. Specifically, in a longitudinal study that controlled for family SES and children's math achievement, mothers' self-reported math-related behaviors (e.g., provision of math-related materials and encouragement of participation in math) predicted their 2nd through 4th grade children's math task-value one year later (Simpkins et al., 2012). However, mothers' math-related behaviors did not significantly predict children's math self-concept. This finding does not rule out the possibility that key socializers' math-related behaviors predict children's math self-concept. For example, math self-concept may be more related to qualitative aspects of math interactions that are not captured by questionnaires. Observing and coding qualitative aspects of parent–child math interactions during non-school math activities and during higher pressure situations such as homework help (e.g., response to errors, praise and criticism, verbal and nonverbal cues that convey math attitudes) would provide information about whether parents' math-related behaviors—and what type of behaviors—may influence their children's math self-concepts and math achievement.

Teachers. Like parents, teachers' perceptions of their students' math ability predict students' math self-concept and interest in math during the elementary school years (Upadyaya & Eccles, 2015; Upadyaya et al., 2014). Further, teachers' math expectations predicted 5th grade students' math achievement controlling for students' prior math achievement, a relation that was partially mediated by students' math self-concept (Friedrich et al., 2015). As was the case for parents, the relation of teachers' math expectations and children's math self-concept may become stronger over development, as shown by a study of 1st to 6th grade students (Wigfield et al., 1997). Thus, over development, children may be increasingly internalizing the math expectations of key socializers.

Different Expectations and Value of Math for Boys and Girls. Parents and teachers tend to have lower expectations of math for girls than boys across a wide range of ages, beginning in elementary school, even though there are no gender differences in their math achievement (Eccles et al., 2000; Herbert & Stipek, 2005; Jacobs, 1991; Mizala et al., 2015; Tiedemann, 2000b; Upadyaya et al., 2014). Further, elementary school teachers' lower perceptions of girls' than boys' math ability predict an increase in the gender-related math achievement gap (favoring boys) between boys and girls who had performed similarly earlier in development (Lubienski et al., 2013; Robinson-Cimpian et al., 2014). Additionally, parents value math competence more for their high school boys than for their high school girls, even in countries where mothers have relatively high representation in STEM careers (Stoet et al., 2016). Moreover, children are aware that key socializers' hold more positive beliefs about boys' than girls' math ability. For example, a study of 4th and 6th grade students in Israel showed that girls believe their parents and teachers think they are worse at math than boys (Markovits & Forgasz, 2017). Additionally, girls perceive their math achievement as being less important to their parents than boys do, a gender difference that is larger in more developed countries (Stoet et al., 2016).

Conclusions. Key socializers' child-specific math beliefs are related to children's math self-concept and math achievement. Key socializers' math-related behaviors are likely playing a role in this relation, but more work is needed to understand what specific behaviors influence children's math self-concept. Further, key socializers have lower math expectations and think math is less valuable for girls than boys, which could explain why girls have a lower math self-concept than boys.

Key socializers' child-specific math beliefs may be influenced by their self-relevant math attitudes (e.g., math anxiety) and general math attitudes (e.g., math-gender stereotypes as discussed in the section on that topic), which may influence their math-related behavior and differential math-engagement with boys versus girls. In turn, these behaviors may influence children's math attitudes and achievement. To increase our understanding of how key socializers' math attitudes affect children's math attitudes and achievement, we need to more closely examine the nature of children's math interactions with key socializers.

Interventions

Improving Domain-Specific Self-Concept. Domain-specific self-concepts have been found to be malleable. A meta-analysis of students from elementary to high school showed that domain-specific interventions are particularly effective when they involve praise-feedback—which relates to children's mindsets. However, consistent with Dweck's theory, certain kinds of praise were more effective than others (see Mindset/Implicit Theory section; O'Mara et al., 2006). Interventions were also more effective when they were administered by a teacher than an experimenter. This finding suggests that key socializers' behavior (e.g., praise-feedback) could improve children's domain-specific self-concepts. Further, an intervention in which teachers provided their middle school students with feedback indicating that they held high expectations for their achievement and believed they would meet those expectations improved students' likelihood of submitting an assignment and the quality of the assignment, particularly for African American students who mistrusted their school (Yeager et al., 2014). Together, these findings suggest that specific aspects of socializer-child interactions may influence children's math attitudes and achievement. Thus, one way to improve children's math attitudes and achievement may be through positive math interactions with key socializers who hold high expectations for children's math achievement.

Improving Parents' Child-Specific Math Beliefs. Parents' child-specific math beliefs also have been found to be malleable. A math app designed for parents and 1st graders to engage in together, which we discussed in the Math Anxiety section, increased parents' expectations and value of math for their children (Schaeffer et al., 2018; see EMAA model, Fig. 1). Further, the intervention eliminated the relation between parents' higher math anxiety and their lower math expectations and value. Moreover, breaking this link helped explain why the intervention improved the long-term math achievement of children whose parents had high math anxiety. This finding suggests that providing parents with math activities that promote positive math interactions with their children improves parents' child-specific math beliefs, which in turn improves children's math achievement.

Improving Children's Identification with Math. We discuss an intervention that targeted another important math attitude: identification with math (Cvencek et al., 2020). The intervention was administered to 3rd graders in Madrid. Children in the intervention group a) heard positive attributes about their in-group's math achievement, b) physically approached math by pulling a lever toward themselves for math words and away from themselves for non-math words, c) heard interesting sound cues linked to math, and d) expressed that they are good at math and that math is important for them. Compared to a control condition, the intervention increased children's implicit (i.e., how much they linked "me" with "math") and explicit identification with math. The promising results of this intervention raise the question of whether certain elements of this intervention (e.g., having children express that they are good at math) would also improve children's math self-concept.

Conclusions. Domain-specific self-concept is malleable. One effective way to improve children's math self-concept may be through supporting positive math interactions with key socializers. Interventions that focus on children themselves also show promise. It is possible that combining these approaches would yield more powerful effects than either approach alone. Whether the effectiveness of different interventions varies by children's age or culture are important areas for future research.

What we know and questions for future research

By 1st grade—and perhaps by preschool—math self-concept predicts math achievement. Similar to findings with math anxiety, this link may emerge by math achievement-related experiences first influencing math self-concept (see Fig. 1). We reiterate that an important next step is to understand how children are interpreting their math achievement-related experiences. For instance, the classroom environment and emphasis on comparisons of students' performance may play a role in children's math self-concept. Interventions may be more successful at improving children's math self-concept and ensuring they maintain a high math self-concept, if they take both a cognitive and affective approach by targeting math self-concept (how students feel about their math ability) as well as math achievement and children's interpretation of their math achievement-related experiences (improving children's learning and their focus on growth of their math skills). This combined approach may be particularly effective in the long-term because improving math self-concept without improving math achievement could result in unrealistic high beliefs about math achievement. To better understand the mechanisms underlying the math achievement * math self-concept relation, researchers have suggested the use of interviews, diaries, and observations (Eccles & Wigfield, 2020). These methods could provide insight into children's beliefs about whether math ability, including their own, is fixed or malleable. In addition, these methods could shed light on how they interpret their math achievement-related experiences and the messages key socializers convey.

Indeed, key socializers' child-specific math beliefs play an important role in children's math self-concept and math achievement, perhaps because their child-specific math beliefs predict the quantity and quality of math behaviors they engage in with children (see Fig. 1). Interventions targeting math attitudes and math behaviors in both key socializers and children could be particularly effective in breaking the link between key socializers' negative math attitudes and children's negative math attitudes and lower math achievement. As is the case for math anxiety, girls have a more negative math self-concept than boys by 5th grade—and perhaps by kindergarten or 1st grade—which could potentially be explained by the lower math expectations key socializers hold for the math success of girls than boys. We further discuss the relations of key socializers' math-gender stereotypes, their gender-biased math expectations and their gender-biased math behaviors in the Math-Gender Stereotypes section.

Another question in need of exploration is whether and how young children's math self-concept relates to their math behaviors. Understanding whether young children's low math self-concept is associated with avoidance within math situations could improve our understanding of whether math self-concept influences behaviors important for math learning (e.g., practice solving problems; using advanced math strategies; engagement with math activities at home).

The math anxiety * math self-concept relation raises the question of whether one of these math attitudes influences the other. Understanding the direction of this relation could inform our understanding of whether intervening on one of these math attitudes is more likely to influence the other than vice versa. Further, it is important to examine the relation of mindset with each of these math attitudes, as mindset is malleable and linked to learning behaviors. Thus, it is possible that mindset interventions might also increase math self-concept and decrease math anxiety.

Mindset/Implicit Theory

An influential motivational theory, developed by Dweck and colleagues, posits that people differ in their mindset about intelligence, with some espousing a growth mindset of intelligence (also referred to as an incremental theory), believing intelligence is malleable, and others espousing a fixed mindset of intelligence (also referred to as an entity theory), believing that intelligence is unchangeable (e.g., Dweck, 1999; 2003; 2008; Dweck & Leggett, 1988; Dweck & Yeager, 2019). Importantly, mindset has been found to be part of a motivational framework associated with a set of beliefs and behaviors that are either adaptive or maladaptive. People with a growth mindset are thought to have an adaptive motivational framework that is characterized by having learning goals and a preference for challenging tasks that can improve ability, a belief that high effort improves ability, and a mastery orientation in the face of failure. In contrast, people who have a fixed mindset are thought to have a maladaptive motivational framework that is characterized by having performance goals and a preference for easy tasks that allow one to prove one's ability, a view that high effort signifies low ability, and a helpless orientation in the face of failure (see Dweck & Yeager, 2019 for review). Over time, these adaptive and maladaptive frameworks are associated with different levels of learning and achievement, including math achievement (e.g., Blackwell et al., 2007; Dweck & Elliott, 1983; Hong et al., 1999).

Numerous studies and meta-analyses find a relation between mindset and a wide range of academic outcomes, including achievement levels, achievement goals, learning strategies, and expectations for success (Burnette et al., 2013; Sisk et al., 2018). However, meta-analyses show that these relations are small and heterogeneous, typically found for students who are lower achieving and from lower SES backgrounds but not other groups (Sisk et al, 2018). This finding is consistent with Dweck's theory that mindset is most important in the face of challenge, and thus it makes sense that groups who experience academic challenges are most affected by mindset (e.g., Blackwell et al., 2007; Dweck, 1986; 2007; 2008).

Our review focuses on the growing body of research on the early development of motivational frameworks, and the relation of these attitudes to children's math achievement Children's motivational framework is typically measured by asking mindset questions about whether abilities are fixed versus changeable and by asking questions about learning versus performance goals, which tap children's focus on improving or proving their abilities, respectively. Unlike math anxiety and math self-concept, these questions typically focus on general ability/intelligence, rather than specifically on math ability. Nonetheless, mindset has been posited to be particularly important for success in math because mindset is particularly important for challenging tasks, and math is commonly viewed as challenging (Blackwell et al., 2007; Dweck, 1986; 2007; 2008; Gunderson et al., 2017; Licht & Dweck, 1984; Eccles et al., 1993; Stodolsky et al., 1991; Yeager & Dweck, 2012; Yeager et al., 2019).

To preview the findings of our review, children's motivational framework emerges by 1st grade, and by this time they have a more fixed mindset about adult jobs that require math than about adult jobs that require reading (Gunderson et al., 2017). Our review also shows that children's achievement goals – performance or learning – may be more tightly linked to their math achievement than is their mindset. Further, mindset and achievement goals may be less related in young children than in older children, a finding consistent with Dweck's (2002) proposal that elements of young children's motivational frameworks may not be as cohesive as those of older children and adults. Another important finding is that similar to math anxiety and math self-concept, children's early math achievement predicts their later mindset/motivational framework more strongly than the reverse, highlighting the importance of early math learning (Gunderson, Park, et al., 2018). In terms of gender differences, there is evidence that girls have a more fixed motivational framework than boys. Moreover, by middle school, having a growth mindset is more important for girls than boys in terms of math outcomes. Finally, there is evidence that the key socializers' mindsets are related to their behaviors, which in turn contribute to children's achievement (e.g., Dweck, 2008; Wigfield et al., 2015; Park et al., 2016). In terms of mindset interventions, there has been little work with young children, and an important question is whether initiating mindset/motivational framework interventions early, before the components of the framework are tightly intertwined, leads to more robust math outcomes.

Development of mindset/implicit theory

Emergence and Developmental Changes in Mindset/Motivational Framework. Studies with young children indicate that mindset about intelligence emerges by early elementary school and perhaps as early as preschool (e.g., Cain & Dweck, 1995; Cimpian et al., 2007; Gunderson et al., 2013; Gunderson, Park, et al., 2018; Gunderson, Donnellan et al., 2018; Good et al., 2003; Kinlaw & Kurtz-Costes, 2007; Miele et al., 2013).

Perhaps related to young children's strong essentialist beliefs (e.g., Gelman et al., 2007), many studies report that growth mindsets are stronger in older than younger elementary school children (Park et al., 2016; Gonida et al., 2006; Gunderson et al., 2017; Gunderson, Donnllan, et al., 2018; Haimovitz et al., 2011; Muradoglu & Cimpian, 2020; Pomerantz & Saxon, 2001; Stipek & Gralinski, 1991). For example, Stipek & Gralinski (1991) found a decrease in children's fixed mindset between 3rd and 6th grades. However, other studies do not find developmental differences in mindset during the elementary school years (Bempechat et al., 1991; Kinlaw & Kurtz-Costes, 2007; Pomerantz & Ruble, 1997). There is also some indication that the developmental shift toward a stronger growth mindset may not be linear, as adolescents and adults in the U.S. and China have a more fixed mindset than younger children (Ablard & Mills, 1996; Cheng & Hau, 2003). Considered together, these findings suggest a U-shaped curve such that mindset moves from being more fixed to more growth oriented over the course of elementary school, and then becomes more fixed again during adolescence, perhaps associated with the transition to the more competitive environments of middle and high school.

Development of Ability Conceptions. When children of different ages are asked questions about mindset about intelligence/ability, their answers may be influenced by their conception of ability – do they differentiate ability and effort or think of these constructs as one and the same. This is a debated issue in the field. Some researchers report that 4- to 5-year-olds, like older children, believe that a child who succeeds on a task with less effort has higher ability than a child who achieves the same success with more effort (Muradoglu & Cimpian, 2020; Sierksma & Shutts, 2020). In contrast, other researchers find that children are more likely to conflate ability and effort (greater ability = greater effort) until at least 5th grade (e.g., Droege & Stipek, 1993; Folmer et al., 2008; Rholes & Ruble, 1984; Nicholls, 1978; Nicholls & Miller, 1984; Pomerantz & Ruble, 1997; see Dweck, 2002; Muenks & Miele, 2017 for reviews). Further, there is evidence that young children's mindsets are organized around general notions of "goodness-badness" rather than around ability (Frey & Ruble, 1985; Heyman et al., 1992; Heyman & Dweck, 1998; Stipek and Daniels, 1990; see Dweck, 2002 for review). In addition, young children are generally more optimistic about their abilities than older children, and perhaps related to this, math attitudes are less closely related to math achievement in younger children than older children (Benenson & Dweck, 1986; Nicholls & Miller, 1984; Eccles et al., 1993; Gunderson, Park, et al., 2018; see Dweck, 2002 for review).

In addition to developmental changes in how children think about the relation of ability tand effort, there also appear to be differences that depend on timeframe and context (e.g., Muenks & Miele, 2017; Nicholls, 1978; Nicholls & Miller, 1984). For example, individuals may believe that high effort is associated with lower ability in the short run but may believe that high effort is associated with higher ability in the long run. In addition, subject matter and associated teaching practices may play a role in individuals' perception of the relation of effort and ability. Notably, in outcome-focused, competitive classroom environments, which are common in math, effort and ability may be viewed as negatively related whereas this may not be the case in discussion-based language arts and social studies classes. Further, mindset appears to be related to how the effort * ability relation is viewed when the relation is ambiguous (e.g., Student A who only studies right before a test ranks 10th whereas Student B, who is a diligent student, ranks 1st). Undergraduates in Hong Kong with a growth mindset were equally likely to decide that Student A or Student B is smarter whereas those with a fixed mindset were less likely to select Student B than Student A as smarter. This pattern is consistent with the tendency of individuals with a fixed mindset to associate high effort with low ability (Hong et al., 1999).

In considrering developmental change in mindset, it is important to consider children's conception of ability as well as these other factors. For example, young children may think of ability as effort, perhaps because effort is more observable than ability and/or because early learning environments are more likely to emphasize effort than those of older children (Dweck, 2002; Eccles et al., 1984; Muradoglu & Cimpian, 2020; Rosenholtz & Rosenholtz, 1981; Stipek & Daniels, 1988). Morevoer, if they conflate ability and effort, their answers to mindset questions may actually reflect their thinking about effort rather than about ability. For example, when they are asked a mindset question such as "You can't really change how smart you are" they may think they are being asked about whether you can change how hard you work. If this is the case, it would influence our interpretation of what appears to be an increase in growth mindset over the course of elementary school.

Development of Motivational Frameworks. There is also evidence that children's motivational frameworks become more cohesive (i.e., its elements become more inter-connected) during elementary school. This is shown by increases in the strength of the relations between their mindset, achievement goals, and responses to failure (Dweck, 2002; 2003; Kinlaw & Kurtz-Costes, 2007). For example, Kinlaw & Kurtz-Costes (2007) found that 2nd and 4th graders' mindsets and achievement goals (i.e., growth mindset and learning goals and fixed mindset and performance goals) were more strongly related than kindergarteners'.

Developmental change in the cohesiveness of motivational frameworks is also supported by older children showing a stronger relation of mindset to mastery versus helpless responses following failure than younger children (Cain & Dweck, 1995; Kinlaw & Kurtz-Costes, 2007). For example, Cain and Dweck (1995) found that 5th graders' mindset was significantly related to their helpless versus mastery responses after failure, but this was not the case for 1st and 3rd graders (Cain & Dweck, 1995). However, when 1st graders in this study were asked why some students perform well in school and others do not, those who showed a helpless response after failure were likely to provide explanations that focused on outcomes (e.g., students get a lot right or wrong), whereas those who showed a mastery response after failure were likely to provide explanations that focused on process (e.g., students study a lot). Cain and Dweck (1995) suggest that differences in young children's outcome versus process focus (which may be related to performance versus learning goals, respectively) may be foundational to building maladaptive or adaptive motivational frameworks that are only later connected to mindset. Consistent with this possibility, in a longitudinal study of 4th to 6th graders, Pomerantz and Saxon (2001) found that earlier achievement goals significantly predicted later mindset whereas earlier mindset did not predict later achievement goals.

Surprisingly, however, a study of 1st to 8th graders found that mindset and achievement goals were not significantly related in any age group (Gunderson, Donnellan, et al., 2018). Differences in study results might be explained by the use of different measures to assess children's achievement goals. Notably, Gunderson, Donnellan et al. (2018) used abstract questions (e.g., "I like school work that I'll learn from even if I make a lot of mistakes"), which were likely more difficult for children than the more concrete question used by Kinlaw and Kurtz-Costes (2007; e.g., "How much would you like to do mazes that are "very hard" so you could "learn more about doing mazes?"). Disparities in findings across studies underline the need to examine children's answers to differently worded questions about ability that aim to assess the same underlying construct, e.g., the different questions used in these two studies aimed to assess learning goals. These findings also raise the possibility that some children have a more mixed motivational framework, with certain elements consistent with a growth mindset and others consistent with a fixed mindset.

Considered together, these findings highlight the need for longitudinal studies that assess different elements of children's motivational framework (mindset, achievement goals, responses to failure, and ability conceptions). Such studies are essential to gaining a more complete understanding of the development of motivational frameworks and their relation to achievement. Additionally, to understand whether mindset/motivational frameworks develop differently for math than for other academic subjects, it is important to gather this information for multiple academic domains.

Mindset About Math Ability. Multiple researchers have suggested that mindset about ability is domain specific, with mindset about math ability being more fixed than mindset about other academic abilities (e.g., Blackwell et al., 2007; Dweck, 1986; 2007; 2008; Gunderson et al., 2017; Licht & Dweck, 1984). However, only a few studies have examined the domain specificity of mindset in children of different ages. Gunderson et al. (2017) found that 1st to 2nd graders, 5th to 6th graders, 10th to 11th graders, and college students have a stronger fixed mindset about math ability than about reading/writing ability when asked about adult jobs that require these skills. However, unlike high school and college students, the younger groups did not hold different mindsets for math success versus reading/writing success in their own grade. Gunderson et al. (2017) suggest that children may first apply socially learned beliefs to the group that taught them these beliefs (e.g., to adults) or alternatively they may not view the math they are learning as particularly difficult, and therefore may not yet have a more fixed mindset about math ability versus reading ability for children in their grade (Dweck, 2003; Licht & Dweck, 1984).

In contrast to Gunderson et al.'s (2017) findings, Stipek and Gralinski (1991) found that children's mindsets about math and social studies abilites were highly related, loading onto a single factor. This may be because children were thinking about math in their own grade rather than adult jobs that require math. In general, while researchers have posited that mindset about math may be more fixed than mindset about other academic domains, we need to determine whether this depends on whether participants are thinking about children's or adults' abilities. Moreover, if domain differences are found, we need to understand the factors that contribute to these differences (e.g., whether or not children think of math as a particularly difficult subject).

Relation of Mindset/Motivational Framework and Math Achievement Outcomes. Many studies find that mindset is related to math achievement-related outcomes, including test scores, grades, and beginning in middle school, math course taking (Aronson et al., 2002; Blackwell et al., 2007; Claro et al., 2016; Gunderson et al., 2017; Romero et al., 2014). For example, students with a growth mindset about intelligence showed improvement in math grades between the fall of 7th grade and the spring of 8th grade controlling for initial math achievement, whereas those with a fixed mindset did not (Blackwell et al., 2007). Similarly, a longitudinal study showed that 6th graders with a growth mindset had higher grades overall and took more advanced math courses through the fall of 8th grade, an important predictor of future STEM achievement (Romero et al., 2014). Another study found that the mindset * math achievement relation is moderated by math achievement level, such that having a fixed mindset in 10th grade negatively predicted math achievement in 12th grade controlling for 10th grade math achievement, but this was only the case for students in the bottom quartile of math achievement (Hwang et al., 2019). Of note, this finding is consistent with intervention studies and meta-analyses, which show that mindset is more consequential for the achievement outcomes of lower performing students (e.g., Sisk et al., 2018; Yeager et al., 2019).

Suggesting that the mindset * math achievement relation may first emerge sometime between 6th and 10th grades, Gunderson et al. (2017) examined the relation of mindset to math grades across a broad age range and found a relation of mindset and math grades in 10th-11th graders and college students but not in 1st-2nd graders or 5th-6th graders. In another study, Gunderson and colleagues found that 1st and 2nd graders' math achievement predicted the achievement goal but not the mindset component of their motivational framework (Gunderson, Park, et al., 2018; Park et al., 2016). Taken together, these findings suggest that children's early math achievement may be more closely related to their achievement goals than to their mindset (Cain & Dweck, 1995; Pomerantz & Saxon, 2001).

The fact that there is a relation between young children's early math achievement and etheir achievement goals raises the question of causality. Do learning goals lead to higher math achievement, does higher math achievement lead to learning goals, or is this relation bidirectional? Gunderson, Park, et al. (2018) examined this question in a lagged longitudinal study, testing 1st and 2nd graders in the fall and spring of the school year. Their findings show a reciprocal relation between math achievement and the achievement goal orientation component of motivational framework, but the relation of fall math achievement to spring achievement goal was stronger than the reverse, by a factor of more than 2. In contrast, fall math achievement predicted spring mindset but fall mindset did not predict spring achievement. These findings echoes the math achievement * math attitude relations found for math anxiety and math self-concept (e.g., Arens et al., 2016; Ganley & Lubienski, 2016; Gunderson, Park, et al., 2018), suggesting that early math achievement sets the stage for positive or negative math attitudes. As pointed out by Gunderson, Park, et al. (2018), these findings suggest that children's optimism about their abilities does not shield them from their actual early math achievement having consequences for their math attitudes and motivations.

Domain Specificity of the Relation of Mindset/Motivational Framework and Math Achievement. Although many studies report a relation between mindset about intelligence and math achievement, only a few studies have examined whether this relation is domain specific. There are multiple reasons why mindset may be more related to math achievement than to achievement in other academic subjects. First, people commonly believe that success in math requires a special talent or brilliance, which is consistent with having a fixed mindset about math ability (Leslie et al., 2015; Meyer et al., 2015). In addition, many researchers have hypothesized that mindset may be more strongly related to math achievement because math is commonly viewed to be a challenging subject and mindset is most important in the face of challenge (Dweck, 1986; 2007; Licht & Dweck, 1984; Eccles et al., 1983; Stodolsky et al., 1991).

Is there evidence that mindset is more important to math achievement than to achievement in other academic subjects? Results of a lagged correlational study with 1st and 2nd grade children indicates that having an incremental motivational framework at the beginning of the school year predicted higher math achievement—but not higher reading achievement—at the end of the school year (Gunderson, Donnellan, et al., 2018). This finding may reflect the importance of an adaptive motivational framework for math achievement, perhaps because children view math as more challenging than reading in these early grades (e.g., Dweck, 1986; Licht & Dweck, 1984; Stipek & Gralinski, 1996).

A large mindset intervention study with 9th grade students also examined the question of the domain specificity of mindset. Findings showed similar positive effects for core grades (math, science, English/language arts, and social studies) and for math and science grades considered separately. As pre-registered, these effects were specific to lower-achieving students, in line with previous findings and theories that posit a growth mindset is most important in the face of challenge (Yeager et al., 2019). However, the intervention did result in increased frequency of advanced math course-taking, an effect that was not moderated by students' achievement level. If this change in course-taking is specific to math, this would support the hypothesis that mindset is especially important to math outcomes.

Other studies have addressed a different question about the specificity of the mindset * math relationship, asking whether mindset about math ability is more closely related to math achievement than mindset about general intelligence. In support of this possibility. Burkley et al. (2010) found that female undergraduates with a fixed mindset about math ability reported less identification with math, less interest in pursuing a math major or career, and less enjoyment of math after receiving negative feedback about their performance on a math test described as measuring "natural math ability," relations that held controlling for mindset about intelligence. It is not known whether this is also true for males, for younger students, and outside of a failure feedback context. Similarly, Gunderson et al. (2017) found that high school and college students' mindset about math ability was positively related to their math competence beliefs, math enjoyment, and math grades, controlling for their mindset about reading/writing ability. Gunderson et al. (2017) also examined these relations in 1st to 2nd graders and 5th to 6th graders but did not find any significant relation of mindset about math ability or mindset about reading/writing ability to math achievement, consistent with the view that other aspects of children's motivational framework (i.e., their achievement goals) may be more connected to math outcomes at early ages (Dweck, 2002; Gunderson, Park et al, 2018).

Relation of Mindset/Motivational Framework to Other Math Attitudes. Gunderson, Park, et al. (2018) examined the relation of 1st and 2nd graders' motivational framework (mindset and achievement goals) and their math anxiety. Fall entity framework predicted spring math anxiety but the reverse was not the case. Separating the components of the framework, findings showed that fall performance goals significantly predicted spring math anxiety but fall fixed mindset did not predict spring math anxiety. A study of high school students in Romania found that mindset about intelligence and mindset about math ability were both related to math self-efficacy (i.e., confidence in one's ability to perform well in math; Todor, 2014). An unanswered question is whether this relation is also present in younger children or whether mindset, either about intelligence or math ability in particular, only becomes related to other math attitudes later in development.

Based on our review, we hypothesize that the achievement goal component of motivational frameworks may be foundational to math anxiety, in line with our proposed EMAA model (see Fig. 1). That is, when children embrace learning goals with respect to math, this may lead to lower math anxiety, moreso than lower math anxiety leads children to embrace learning goals. This hypothesis could be tested by examining whether intervening on achievement goals leads to lower math anxiety whereas intervening on math anxiety does not increase learning goals.

Conclusions. Early math achievement predicts achievement goals (learning versus performance) more strongly than the reverse, as was the case for math anxiety and math self-concept. Thus, children's early math achievement may be fundamental in setting their math attitudes on a positive or negative trajectory, with these relations becoming bidirectional by adolescence. Children's achievement goals, in turn, are predictive of their math anxiety by early elementary school, a relationship that is directional rather than reciprocal. In contrast, the mindset component of young children's motivational framework does not predict children's math achievement or their math anxiety. However, by middle school, having a growth mindset predicts children's math achievement, particularly in the face of challenge.

There is also evidence that young children may hold a more fixed mindset about math ability than about reading/writing ability by early elementary school, at least when they consider what it takes for adults to succeed in math-intensive careers. Asking children a broad range of questions about math versus reading/writing ability (e.g., Does someone's ability change when they change schools? Does a student who works hard and gets a perfect score have more/less ability than a student who gets a perfect score without working hard?) would advance our understanding of how children conceptualize abilities in different academic domains (Pomerantz & Ruble, 1997). Further, interviewing children about their own successes and failures in different academic domains could inform our understanding of the development of motivational frameworks and how these relate to achievement.

Another way to extend work on the development of motivational frameworks and its relation to math outcomes is to examine the development of interest mindsets – the belief that interests are relatively unchangeable (fixed mindset about interests) or develop (growth mindset about interests). Research with college students shows that mindset about interests (e.g., interests are intrinsic and need to be discovered (fixed) or interests need to be cultivated) (growth)) have consequences for maintaining interest in the face of challenge, controlling for mindset about ability (e.g., O'Keefe & Harackiewicz, 2017; O'Keefe et al., 2018). Given that math is a challenging subject for many students, it is important to assess when mindset about interest in math develops and how this relates to mindset about math ability and to math achievement.

Gender differences

Gender Differences in Mindset. Some studies find that females have a more fixed mindset than males (Dweck et al., 1978; Gunderson et al., 2013; Gunderson, Park, et al., 2018; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Stipek & Gralinski, 1991; Todor, 2014; Verniers & Martinot, 2015), but other studies report that there is no gender differences in mindset (Ablard & Mills, 1996; Ahmavaara & Houston, 2007; Gunderson et al., 2017; Hwang et al., 2019; Romero et al., 2014). These inconsistencies may be attributable to variations in how mindset is measured (Verniers & Martinot, 2015), to socio-cultural differences, or to inadequate power to detect a small, but real gender difference. Importantly, although there are inconsistencies, studies that find a gender difference generally report that females have more of a fixed mindset/motivational framework than males.

Gender Differences in Ability/Effort Attributions. A meta-analysis examining math-related attitudes across a broad range of ages from childhood to adulthood showed that females are more likely than males to attribute failure in math to a lack of ability ($d = -0.23$; Hyde, Fennema, Ryan et al., 1990). This makes sense since having a fixed mindset is most consequential in the face of failure and females may hold a more fixed mindset than males as summarized above. Hyde, Fennema, Ryan et al. (1990) also found that males are more likely than females to attribute success in math to ability ($d = 0.35$). Importantly, the female pattern of attributions—attributing failure in math to lack of ability and success in math to effort—is associated with a learned helplessness orientation, which is more common in females and is associated with a fixed mindset and low expectations for success (Licht & Dweck, 1984; Ryckman & Peckham, 1987).

Gender Differences in the Strength of the Mindset * Math Achievement Relation. Dweck (2007) hypothesized that having a fixed mindset may be more harmful to the math achievement of females than males. This is because females with a fixed mindset are particularly likely to display a helpless response when they confront difficulties or confusion, which commonly arise during math learning (also see Licht & Dweck, 1984). The flip side of this is that a growth mindset may buffer female students' tendency to adopt a helpless response when they experience difficulties (e.g., when math concepts are challenging). Consistent with this hypothesis, Degol et al. (2018) found that the math grades of high school boys and girls with a fixed mindset did not differ, whereas the math grades of girls with a growth mindset were higher than those of boys with a growth mindset (Gunderson, Park, et al., 2018). This gender by mindset interaction was fully mediated by expectancies for success in math, which were more strongly associated with girls' than boys' growth mindset.

In terms of development, young boys and girls may not differ in terms of the consequences of having a fixed versus growth mindset/motivational framework. That is, even though 1st and 2nd grade girls had a more fixed motivational framework than boys at the beginning of the school year, driven by boys' greater preference for challenging tasks, there was no gender difference in how motivational framework related to end of school year math achievement (Gunderson, Park, et al., 2018).

Gender Differences in the Relation of Mindset/Motivational Framework to Other Math Attitudes. There is no evidence that males' and females' motivational frameworks relate differently to their math attitudes, but research on this topic is limited. In a study of 1st and 2nd graders, Gunderson, Park et al. (2018) found that fall achievement goals, but not mindset, predicted spring math anxiety and there was not a gender difference in this relation. There is evidence of a gender difference in the relation of mindset to math achievement and math interests by middle school. Notably, Huang et al. (2019) examined how 7th graders' mindset, math anxiety, and math self-efficacy relate to each other and to students' math and science career interests, controlling for math achievement. Path analyses revealed that for both boys and girls, math self-efficacy was negatively related to math anxiety and positively related to having a growth mindset. However, as would be expected, boys with higher math achievement had lower math anxiety, a stronger growth mindset, and higher career interests in math and science than boys with lower math achievement. In contrast, girls' math achievement was not significantly related to their math attitudes or to their math and science career interests. This may be because math-gender stereotypes disrupt these expected relations for girls, a topic we consider in the next section (Jacobs, 2005). Further, for boys, the association of growth mindset with math and science career interests was mediated by their math self-efficacy, whereas this was not the case for girls. In fact, girls' math self-efficacy was not related to their math and science career interests. These findings suggest that by middle school, relations between math achievement, multiple math attitudes, and STEM career interests differ for boys and girls. Importantly, understanding the development of math attitude * math achievement relations in boys and girls holds promise for elucidating gender differences in STEM career interests.

Conclusions. In sum, there is not strong evidence of an early gender difference in mindset, although studies that report a difference report that girls have more of a fixed mindset than boys. However, having a growth mindset may be more important for girls' than boys' math outcomes by middle school, perhaps because it decreases girls' tendency to adopt a helpless response and protects them from the negative effects of math-gender stereotypes.

Key socializers

Surprisingly, there is little or no relation between the mindset of key socializers and the mindset/motivational framework of children. Instead, experimental and field studies indicate that key socializers with different mindsets tend to engage in different behaviors with children, and it is these behaviors that are related to children's mindset/motivational frameworks and math achievement-related outcomes (Dweck, 2008; Gunderson et al., 2013; Kamins & Dweck, 1999; Mueller & Dweck, 1998; Pomerantz & Kempner, 2013; Park et al., 2016; Yamamoto & Holloway, 2010; Wigfield et al., 2015). Indeed, experimental studies show that certain kinds of input have at least short-term causal consequences for children's mindsets/motivational frameworks (Kamins & Dweck, 1999; Mueller & Dweck, 1998; Cimpian et al., 2007).

Parents' Mindsets. Parents' mindsets have been linked to whether they emphasize performance or learning goals while interacting with their children. For example, Moorman and Pomerantz (2010) examined how mothers interacted with their 6- to 9-year-old children on a puzzle task after they had been induced to hold a fixed or growth mindset about the task. Those in the fixed mindset condition showed more performance-oriented support, exerted more control of the interaction, and showed more negative affect than those in the growth mindset condition. Muenks et al. (2015) extended this research to academic math and reading tasks, and in a correlational study found that parents with fixed mindsets about math and reading reported engaging in relatively more performance-oriented help and less mastery-oriented help compared to parents with incremental mindsets. These findings suggest that interventions that help parents adopt growth mindsets could improve their interactions with their children, which in turn could positively affect children's motivation and learning.

Parents' Praise. Studies of parent-child interactions show that the type of praise parents provide predicts children's mindsets and achievement goals. A longitudinal study examining naturalistic parent-child interactions showed that toddlers who received higher proportions of process praise (process praise/total praise) had more incremental motivational frameworks in 2nd grade (Gunderson et al., 2013). The children who had received more early process praise from their parents also had higher math and reading achievement in 4th grade, mediated by having an incremental motivational framework in 2nd grade (Gunderson, Sorhagen, et al., 2018). Consistent with these findings, Pomerantz and Kempner (2013) found that 8- to 10-year-olds whose mothers reported providing more person praise had more fixed mindsets.

Experimental studies reveal similar findings of praise type on children's motivations and behaviors (Corpus & Lepper, 2007; Kamins & Dweck, 1999; Mueller & Dweck, 1998). These studies also showed that after a failure experience, children who had earlier received person praise were more likely than those who had received process praise to attribute the failure to lack of ability, and to report that they enjoyed the task less and did not want to persist. Moreover, children who had received person praise performed worse than they had at baseline on comparable problems whereas those who had received process praise performed better than they had at baseline (Mueller & Dweck, 1998). Experimental studies also show that subtle differences in the language used to praise children can have effects on their motivation and behavior (Cimpian et al., 2007; Kamins & Dweck, 1999; Zentall & Morris, 2010). In a study using a pretend drawing task, 4-year-olds were given praise with either generic language ("You are a good drawer") or non-generic language ("You did a good job drawing"), which map onto person and process praise, respectively (Cimpian et al., 2007). Following this, children were told they had made a mistake (e.g., "forgot to draw the ears of the cat" on their pretend drawing). Children who received generic (person) praise evaluated their performance more negatively and were less likely to persist on the task after failure feedback than those who received non-generic (process) praise. Given the nuanced ways in which the language used to praise children affects their motivation and self-evaluations, it is not surprising that parents' mindsets and children's mindsets are not related (Gunderson et al., 2013).

Of note, there are some contradictory findings regarding the relation of praise and mindset, which may be explained by developmental, gender, and/or methodological differences. For example, Henderlong Corpus and Lepper (2007) found that the motivation of 4th and 5thgrade girls was affected by praise type but this was not the case for boys. In particular, girls showed more interest in tangram puzzles when they were given process praise or product praise than person praise or neutral feedback, whereas boys showed no condition differences, perhaps because gender stereotypes increase the sensitivity of girls to praise. Further, preschool children showed positive effects of all praise types compared to neutral feedback. However, Gunderson, Donnellan, et al. (2018) found that parents' process praise (as reported by children) significantly related to 5th and 8th graders' learning goals, but not to their incremental theories, which is somewhat at odds with other findings (Gunderson et al., 2013; Pomerantz & Kempner, 2013). This discrepancy may be due to the different methods used to collect data on parent praise—direct observation of parent praise by Gunderson et al. (2013) and parent report by Pomerantz and Kempner (2013), versus child report by Gunderson, Donnellan, et al. (2018). It could also be due to the inclusion of older children in the Gunderson, Donnellan, et al. (2018) study, as older children are more likely to associate effort with a lack of ability (Nicholls, 1978), and as a result, may have viewed process praise (e.g., "You worked hard on that") as indicative of their low ability (Lam et al., 2008; see Henderlong & Lepper, 2002) for a comprehensive review of the effects of praise on children).

Parents' Criticism and Failure Feedback. Researchers have posited that parents' "failure mindsets" may have more potent effects on children's ability mindsets than parents' mindsets about intelligence. In a series of studies, Haimovitz and Dweck (2016) found that elementary school and older children were aware of parents' failure mindsets – whether they have a failure as debilitating mindset (a belief that failure inhibits learning) or a failure as enhancing mindset (a belief that failure provides an opportunity to learn), but were not aware of their parents' mindset about intelligence. Moreover, parents with a failure as debilitating mindset reported providing performance-oriented feedback to their child after failure (e.g., worrying about their child's performance; comforting their child for not having enough ability) whereas parents with a failure as enhancing mindset, reported providing learning-oriented feedback to their child after failure (e.g., focusing on the process the child engaged in when studying; expressing the belief that the child can succeed with a change in strategy). Importantly, parents' failure mindset, but not their intelligence mindset, predicted children's intelligence mindset, and this relation was fully mediated by children's perception of their parents' performance versus learning goal orientation. Thus, parents' failure mindset is linked to the feedback they provide children after failure, and this feedback is particularly salient to children. Thus, parents' failure mindset may be more influential in shaping their children's mindset about intelligence than parents' mindset about intelligence.

Other studies report differential effects of perceived parent praise and criticism on achievement goals and mindset (Gunderson, Donnellan, et al., 2018). Interestingly, overall perceived parent praise, and particularly perceived parent process praise, positively predicted children's learning goals. In contrast, overall perceived parent criticism, particularly person criticism, negatively predicted children's mindset about intelligence. These findings underscore the importance of examining the ways that parents, as well as teachers, praise and criticize children of different ages, and how this affects children's mindset, achievement goals, and achievement outcomes. There is also a need to examine whether constellations of praise and criticism differ depending on domain, and how these feedback patterns together may shape children's domain specific achievement goals and mindsets.

Teachers' Instructional Practices. A study of 1st and 2nd grade students and their teachers showed that teachers' mindsets were related to their performance versus mastery oriented instructional practices, which in turn predicted students' motivational frameworks. For example, 1st and 2nd grade teachers' performance oriented instructional practices predicted children having a fixed motivational framework at the end of the school year, controlling for children's motivational framework at the beginning of the school year (Park et al., 2016). In contrast, teachers' mindsets did not predict children's motivational framework even though teachers' mindsets were connected to their instructional practices in expected ways, likely because teachers' beliefs about the malleability of intelligence are less visible to children than their instructional practices (Park et al., 2016). A study carried out in Germany found a negative relation between teachers' fixed mindsets and the math achievement of low performing 4th grade students, but this relation may have been mediated by teachers' instructional practices, which were not examined in the study (Heyder et al., 2020).

Another instructional practice that may affect children's mindset about math ability is comparing children's math ability to that of their peers (Stipek & Daniels 1988; see Dweck, 2002; see Boaler, 2013 for review). Cross-cultural research provides a lens for examining these relations. For example, in many high–achieving Asian countries, effort is emphasized, and children are not grouped by ability. In contrast, in the U.S., ability grouping typically begins in 7th grade and much earlier in England (see Boaler, 2013 for review). An interesting question is how these practices are related to differences in mindset about math ability.

Teachers' Attributions. Laboratory studies have examined how mindset relates to teachers' behaviors and interpretations of children's math performance, as well as how students interpret teacher behaviors. In one study, Rattan et al. (2012) asked undergraduates to imagine being a 7th grade math teacher. Participants were then presented with a scenario in which a student failed a math test. The researchers found that those "teachers" who endorsed a fixed mindset about math ability, were more likely to regard the student who failed as having low math ability. In another study, undergraduates were induced to hold a fixed or a growth mindset about math ability. Those induced to hold a fixed mindset were more likely than those induced to hold a growth mindset to report that they would comfort a 7th grade student who failed a math test about their lack of math ability and would give the student less homework (Rattan et al., 2012). These studies suggest that teachers with a fixed mindset about math ability may engage in behaviors that are deleterious to student math attitudes and achievement.

In support of this possibility, Rattan et al (2012) examined how undergraduates would feel if they received a low score on a calculus test and their teacher either gave them various kinds of feedback: comfort feedback (e.g., "I know you're a talented student in general, it's just not that every student is a math person"), feedback on how to improve their performance, or no feedback. Students in the comfort feedback condition reported that they would have lower expectations about their calculus course grade and lower motivation than those in the other conditions. Additionally, students in the comfort feedback condition perceived their teacher as having a fixed mindset about math and lower expectations for their success in math. These findings suggest that teachers with a fixed mindset negatively affect the math outcomes and interests of their students. An important extension of these studies involves examining whether these findings hold in classroom settings and for students at different grade levels.

Different Input to Boys and Girls. Key socializers provide different input to boys and girls, which may influence children's mindsets. For example, during naturalistic interactions, 1- to 3-year-old boys received more process praise and girls received more non-process praise (person praise and other praise; Gunderson et al., 2013). This difference in praise type was related to boys having a stronger incremental motivational framework than girls at 7- to 8-years-old.

Similarly, elementary school teachers provide girls and boys in 4th and 5th grades with different patterns of feedback (Dweck et al., 1978). Teachers' positive feedback to boys was more associated with their academic success than was the case for girls. In contrast, teachers' negative feedback to boys was less associated with their academic success than was the case for girls. Consistent with these findings, teachers attributed girls' failures more to lack of ability and boys' failures more to lack of motivation. It is, of course, possible that teachers' differential feedback to boys and girls is evoked by gender-related differences in classroom behavior (Rietveld et al., 2004). That is, if boys, on average, are less attentive than girls, this may lead teachers to attribute boys' academic failures to attentional factors and girls' academic failures to lack of ability. However, Dweck et al. (1978) carried out a follow-up experiment where boys and girls were randomly assigned to receive the boy or girl pattern of feedback, and results showed that boys and girls who received the boy pattern of failure feedback viewed the feedback as indicative of their lack of effort whereas boys and girls who received the girl pattern of failure feedback viewed the feedback as indicative of their lack of ability.

Conclusions. In sum, key socializers' feedback appears to be related to children's mindset/motivational framework. Moreover, boys and girls may receive different patterns of feedback from key socializers, and this may affect their mindset/motivational framework, attributions about failure, and achievement. These findings underscore the role of inter-generational interactions in children's motivation and achievement and raise important questions for future research. One of these is whether boys and girls are differentially sensitive to socializers' inputs, and whether this is the case at particular developmental time points. Another is whether key socializers have a stronger impact on children's motivation and achievement in math compared to other subject areas. Dweck (2008) suggests that classrooms that adopt growth mindset practices have positive effects on students' learning outcomes. Relatedly, Boaler (2016) suggests that children develop fixed mindsets about math ability as well as other negative math attitudes because much of their time in math class involves demonstrating their knowledge rather than discussing different ways to solve problems. In other words, teachers' focus on outcomes rather than process in math class could contribute to the development of students' fixed mindsets about math. An interesting question is whether an outcome focus is more common in math classes than in classes such as English and history, where answers are less objectively right or wrong and teaching may be more likely to consist of discussing different viewpoints.

Interventions

Improving Math Achievement. Growth mindset interventions have improved math outcomes, particularly for lower achieving students and students whose math abilities are negatively stereotyped (Blackwell et al., 2007; Good et al., 2003; Yeager et al., 2019). For example, Blackwell et al. (2007) conducted a growth mindset intervention with 7th graders from lower SES backgrounds and assessed whether it improved math learning trajectories from the end of 6th grade through the end of 7th grade. Before the intervention, math grades declined in both groups between the end of 6th grade and the beginning of 7th grade. Post-intervention, the groups diverged, with the math grades of the control group continuing to decrease while those of the intervention group increased. Because math is a challenging subject, and the transition to middle school is challenging for many students, the authors suggest that the mindset intervention might be particularly effective for math at this developmental time point.

Another study examined the effects of different interventions—a growth mindset intervention, an attribution intervention (many students experience difficulty when they move to a new school setting such as junior high school), a combined mindset plus attribution intervention, or a control anti-drug condition—on the math and reading achievement of 7th grade students from largely low-SES students in a rural area (Good et al., 2003). Of note, all the interventions were effective, but they were more effective for girls' than boys' math achievement (more than 1 SD higher than the control group), in line with the hypothesis that mindset and other interventions that address sense of belonging are beneficial for negatively stereotyped groups (Dweck, 2007; Good et al., 2003).

Consistent with the finding that mindset interventions are more effective for low achieving students, a preregistered national mindset intervention with 9th graders found positive and similar effects on both core grades in general and math and science grades, specifically for students whose grades were below the school median (Yeager et al., 2019; also see Sisk et al. (2018) meta-analysis). However, the positive effects of the intervention extended beyond low-achieving students when enrollment in advanced math and science courses was the outcome, an effect that was significantly larger for students in high achieving schools, suggesting that context matters for the effectiveness of mindset interventions.

Although the effects of mindset interventions on achievement are modest, these interventions are also generally short and relatively low cost. It is possible that a series of developmentally appropriate, customized "mindset boosters" might result in larger effects (Yeager et al., 2013).

Conclusions. To recap, mindset interventions improve achievement, including math achievement, but positive effects do not appear to be specific to math. Additionally, mindset interventions may be more effective for students who are facing challenges (e.g., low-achieving students) or who are negatively stereotyped (e.g., females for math ability). Our knowledge of the effectiveness of mindset interventions comes almost exclusively from middle school and older students. Most of the studies included in Sisk et al.'s (2018) meta-analysis of mindset interventions included adolescents or adults, and only two included elementary school children. Indeed, many researchers have theorized that mindset interventions may be particularly effective when students are transitioning into middle school and face many new challenges that result in decreases in academic performance and other difficulties, (Eccles et al., 1991; Good et al., 2003; Simmons et al., 1991). However, it is possible that intervening on mindset/motivational framework at younger ages could have beneficial long-term effects, particularly if interventions continue throughout schooling. It is likely that

Interventions that work with older children will need to be modified for younger children. For example, the incorporation of process praise into interventions might be an effective way to increase younger children's growth mindsets. Another important question is whether interventions that focus on mindset about math ability rather than mindset about ability in general may be more effective in supporting children's math achievement-related outcomes (Yeager & Dweck, 2012). Finally, it is possible that early interventions should focus on achievement goals with young children, as these goals are more closely connected to math achievement than mindset at early developmental time points.

What we know and questions for future research

Mindset and motivational frameworks emerge by early elementary school, and even at these early ages are related to children's math achievement. Moreover, by this age, children may hold more of a fixed mindset for math ability than reading/writing ability when asked about adult jobs that require these skills. As is the case for math anxiety and math self-concept, there is a stronger relation of earlier math achievement to later motivational framework than the reverse, suggesting that early math achievement influences a broad range of children's early math attitudes (see Fig. 1). To test whether these relations are causal, we need to test whether interventions that raise math achievement also improve math attitudes. In addition, certain math attitudes may predict other math attitudes more than the reverse, as the achievement goal component of young children's motivational framework predicts their math anxiety and their math self-efficacy, whereas the reverse relations are not significant (see EMAA model, Fig. 1). Again, although correlational, this finding suggests that intervening on young children's achievement goals might improve other math attitudes.

In terms of gender differences, there is some evidence that girls may have more fixed mindsets than boys, and that this may be linked to differences in how key socializers interact with girls and boys. There is also evidence that having a growth mindset may be particularly important for negatively stereotyped groups (e.g., females) as well as for students with low math achievement.

Key socializers' interactions with children are influenced by the mindsets they have. However, they appear to affect children's mindsets/motivational framework and achievement through their instructional practices and feedback to children, which are related to their mindsets rather than directly via the socializers' mindsets (see Fig. 1 which posits that socializers' attitudes influence their behaviors with children, which in turn influence children). These findings are important in informing intergenerational interventions that might be effective in supporting the development of growth mindsets/motivational frameworks. For example, mindset interventions that focus on key socializers might have larger downstream effects on children's learning if they not only support the development of socializers' growth mindsets, but also make the link between mindsets and instructional practices explicit. Further, it is important to examine whether interventions that specifically focus on mindset/motivational framework about math ability might be more effective in improving math achievement than mindset interventions that focus on intelligence or more general abilities. Alternatively, interventions could be more effective if they focus on socializer-child math behaviors that are associated with adults' mindsets.

We lack information about the effectiveness of mindset interventions with young children, as existing interventions have mainly focused on adolescents and older students. It is possible that mindset/motivational framework interventions may be more effective with younger than older children because their frameworks are less cohesive than those of older children. Thus, intervening early might help prevent the negative relations between math achievement and entity motivational frameworks before multiple maladaptive attitudes become connected to math achievement. Another important question is whether early mindset/motivational framework interventions may have long-term consequences for math outcomes that exceed those for other academic domains, particularly when these interventions are reinforced over time.

Math-gender stereotypes

A pervasive cultural stereotype is "Males are better at math than females." Importantly, this stereotype is negatively related to females' math outcomes and may have the opposite effect on the math outcomes of males (for reviews see J.R. Steele et al., 2007; Nosek & Smyth, 2011). Research shows that this stereotype emerges by early elementary school and is related to math skill at this time, at least for children in Singapore (e.g., Cvencek et al., 2015). As discussed by Kurtz-Costes et al. (2008), one important question is whether the math-gender stereotype increases with age, consistent with Cultural-Experiential Theory. and another is whether this stereretotype develops differently in boys versus girls, e.g., whether it develops earlier in boys because they are the positively stereotyped group, consistent with Social Status Theory.

Like other stereotypes, the math-gender stereotype operates at both implicit (i.e., automatic and unconscious) and explicit (i.e., controlled and conscious) levels (e.g., P.G. Devine, 1989; Greenwald et al., 1998; for review of work with children see Killen et al., 2008). Implicit stereotypes appear to form based on exposure to concepts that are associated with each other (e.g., math and males), regardless of whether one endorses the explicit stereotype that math is for males or that males are better at math than females (e.g., Gregg et al., 2006; Nosek & Smyth, 2011). Thus, both adults and children who show the implicit math-gender stereotype may deny the explicit math-gender stereotype (Greenwald et al., 2009). Further, females who do not endorse the stereotype can still be negatively affected by it, and in both children and adults, the implicit stereotype is typically found to be more strongly related to math achievement-related outcomes than the explicit math-gender stereotype (Ambady et al., 2001; Cvencek et al., 2015; Galdi et al., 2014; Greenwald et al., 2009; Kiefer & Sekaquaptewa, 2007; Nosek et al., 2002, 2007, 2009; Nosek & Smyth, 2011).

By college age, the math-gender stereotype affects more than performance on math tests, and also decreases students' intensions to take math classes, to pursue math intensive-majors, and to enter math intensive careers. Several mechanisms have been proposed to account for these negative effects. One such mechanism is that the math-gender stereotype leads to increased math anxiety, which can deplete working memory resources while doing math. A second mechanism is that the math-gender stereotype can lead to math avoidance (see Schmader & Johns, 2003 for review; Spencer et al., 1999; Tomasetto, 2019). Finally, the math-gender stereotypes may decrease sense of belonging in math classes, math-intensive majors, and math-intensive careers (e.g., Good et al., 2012; Master & Meltzoff, 2020). All these mechanisms may be operative, leading to lower math interest and achievement in females, effects that may be more acute in females from under-represented minorities who are subject to more than one stereotype (Rainey et al., 2018).

To preview the findings of our review, developmental research has shown that the math-gender stereotype emerges by early elementary school, and by this time is negatively associated with the math achievement of girls. Moreover, the implicit stereotype not only emerges prior to the explicit stereotype but is also more related to math outcomes. There is also evidence that the math-gender stereotypes of key socializers relate to children's math self-concepts, and eventually to their math grades. Moreover, socializers' math-gender stereotypes are related to differences in the ways they interact with boys and girls around math, which may mediate the relation of adult stereotypes to children's math outcomes.

Development of math-gender stereotypes in boys and girls

By early elementary school, the math-gender stereotype exacts a toll on girls' math achievement (see Master & Meltzoff, 2020; Régner et al. 2014 for reviews). As is the case for adults, it is important to measure children's math-gender stereotypes using implicit as well as explicit measures, as the latter may be influenced by factors such as personal standards and social desirability effects whereas the former are likely to be more insulated from these effects (e.g., Nosek et al., 2002). Moreover, in children, implicit measures may be more sensitive to stereotypes for two other reasons. First, early experiences may have a stronger effect on implicit than explicit attitudes (e.g., Rudman, 2004). Second, young children may have difficulty introspecting about the relative abilities of groups of people, perhaps due to developmental changes in their conceptions of ability, but do form associations between gender groups (e.g., male) and academic domains (e.g., math) (Dweck, 2002; Folmer et al., 2008; Nicholls, 1978; Nicholls & Miller, 1984).

Emergence and Developmental Change. Young children generally show earlier emergence of implicit than explicit math-gender stereotypes and their implicit stereotypes are more strongly connected to their math achievement outcomes than their explicit stereotypes (Ambady et al., 2001; Cvencek et al., 2011, 2015; del Río et al., 2019; 2020; Galdi et al., 2014; J. Steele, 2003; Muzzatti & Agnoli, 2007; Steffens et al., 2010). Further, some studies show that priming children's gender or the math-gender stereotype prior to a math test increases children's implicit, but not their explicit math-gender stereotype. Thus, by measuring implicit math-gender stereotypes in children, we gain a more comprehensive understanding of the development and impact of these stereotypes on math outcomes than we get from measuring their explicit math-gender stereotypes alone (Meltzoff & Cvencek, 2019; del Río et al., 2020).

Implicit Math-Gender Stereotype. Evidence of the implicit math-gender stereotype by early elementary school comes from studies carried out in various locations around the world (e.g., U.S., Italy, Germany, Singapore, and Chile). However, there are inconsistencies as to whether the stereotype is present in both girls and boys (Cvencek et al., 2011, 2015; del Río et al., 2020), only in boys (del Río et al., 2019), or only in girls (Galdi et al., 2014; Steffens et al., 2010), which may reflect methodological differences, insufficient power, and/or cultural variation.

Although there is ample evidence that the implicit math-gender stereotype emerges early in development, we have limited information about developmental change in the strength of the stereotype. Children's implicit stereotypes appear to be weaker than those of their parents (del Río et al., 2020), consistent with Cultural Experiential Theory (see Kurtz-Costes et al., 2008). However, the magnitude of the implicit stereotype is reported to be constant between 1st grade and 5th grade (Cvencek et al., 2011, 2015; del Río et al., 2020). These findings suggest a possible increase in the implicit math-gender stereotype after children enter middle school and highlight the need for more information about the trajectory of the stereotype.

Explicit Math-Gender Stereotype. Some studies find that young elementary school children show evidence of implicit and explicit math-gender stereotypes (Cvencek et al., 2011, 2015) whereas others find that children show the implicit but not the explicit stereotype, consistent with the view that the implicit gender stereotype emerges earlier (del Río et al., 2019, 2020; Galdi et al., 2014). Of note, correlations between implicit and explicit stereotypes are generally low or not significant, suggesting that different processes may underlie these stereotypes (e.g., Cvencek, 2011, 2015).

There is also some indication that explicit math-gender stereotypes may emerge earlier in boys than girls, consistent with Social Status Theory (see Kurtz-Costes et al., 2008). Muzzatti & Agnoli (2007) asked 2nd through 5th grade Italian children whether boys are better at math than girls, whether girls are better at math than boys, or whether boys and girls are equally good at math. Boys in 2nd grade did not endorse the stereotype but boys in every other grade did, and the explicit stereotype was stronger in 4th and 5th graders than at earlier grade levels. In contrast, 2nd grade girls responded that girls are better at math, 3rd grade girls responded that boys and girls were equally good at math, and it was not until 4th and 5th grade that girls endorsed the stereotype that males are better at math, with stronger endorsement in 5th grade. Gender comparisons showed that boys' explicit math-gender stereotype was stronger than that of girls in the earlier graders but not in 4th and 5th grades. However, such gender differences in the strength of the stereotype may vary depending on culture and/or task as a study carried out in Singapore found that both boys and girls were likely to select a picture of a boy (versus a girl) as liking to do math more, and this was the case as early as first grade (e.g., Cvencek et al., 2015).

There is also evidence that girls' math-gender stereotype may differ depending on whether questions concern the math ability of boys versus girls or women versus men. Girls in 1st to 4th grade showed evidence of the stereotype when asked about adults but not when asked about children, a pattern referred to as "stereotype stratification" (J. Steele, 2003). In contrast, boys showed a bias toward males regardless of whether they were asked about the math ability of children or adults. This likely reflects an 'own-gender bias" because boys also showed a male bias when asked about the spelling ability. For girls, the stratification of the stereotype by age of the target group may mirror seeing more adult males than adult females in STEM professions but seeing that girls perform at least as well as boys in math at school. Thus, when assessing stereotype endorsement, it is important to specify whether questions probing the math-gender stereotype are referring to adults or children.

Variations in Findings. As mentioned, there are variations in findings across studies, particularly with respect to whether there are gender differences in the development of math-gender stereotypes. There are multiple potential explanations for these variations, but more work is needed to determine which explanation(s) is correct. Below, we discuss several approaches that can advance our understanding of the origins and development of the math-gender stereotype.

Cultural Variations. Although studies of children's math-gender stereotypes have been carried out in various cultural contexts, we have little understanding of the factors that influence young children's math-gender stereotypes. One might speculate that the math-gender stereotype might be more robust and emerge earlier in cultural contexts with more gender inequity. However, 15-year-olds taking the PISA test were more likely to report that their parents valued math achievement more for their sons than their daughters in countries with more gender equity, as indexed by the World Economic Forum's Global Gender Gap Index (Stoet et al., 2016). This finding may shed light on why elementary school children in the U.S. and Singapore where there is more gender equity, but not those in Chile, where there is less gender equity, endorse the explicit math-gender stereotype (OECD, 2015). These counter-intuitive findings could be related to the measures used to assess gender equity, which typically consist of global measures such as gender representation in Congress and the life expectancy of men versus women (Global Gender Gap Index), which are quite distal from gender equity in STEM. In fact, as was the case for math ability self-concept, when a more proximal index of gender equity in STEM is used, countries with higher representation of women in STEM had lower science-gender stereotypes (Miller et al., 2015). Increasing our understanding of how particular aspects of cultural context affect children's implicit and explicit math-gender stereotypes and math outcomes holds promise for enhancing our understanding of the factors that contribute to these stereotypes.

Measure Variations. Various measures have been used to assess implicit and explicit math-gender stereotypes in children. For implicit measures, adult IATS are generally presented as written words, but for children, stimuli are either presented as pictures (del Río et al., 2019; Galdi et al., 2014) or as written words that are read aloud in order to control for differences in reading ability (Cvencek et al., 2011, 2015). For explicit measures, children are asked different questions to assess the presence of the stereotype (e.g., whether boys like math more than girls or whether boys have more math ability than girls). Importantly, we do not know whether these questions—about liking or ability—yield the same findings. Understanding how the same children respond to different implicit and explicit stereotype measures is important to interpreting developmental patterns and variations in results across studies. For example, this information would help researchers understand whether a difference in results reflects a difference in measures or a difference that may be attributable to cultural context.

Implicit Measure Variations. An important feature of IATS is that the stereotype measure is calculated by comparing responses to stereotype congruent and incongruent conditions in two different domains, typically math and a verbal domain such as reading when assessing the math-gender stereotype. In the stereotype congruent condition, participants are asked to press one button for boy and math stimuli and another button for girl and reading stimuli. In the stereotype incongruent condition, children are asked to press one button for boy and reading stimuli and the other button for girl and math stimuli. Implicit stereotypes are calculated via an algorithm that compares the speed of making stereotype congruent categorizations versus stereotype incongruent categorizations in the two domains (Greenwald et al., 2003). Thus, the implicit stereotype measure not only reflects one's association of male versus female with math, but also one's association of male versus female with reading. The use of congruent and incongruent pairings in two domains raises the possibility that female-language associations in the absence of male-math associations may be erroneously interpreted as reflecting an implicit math-gender stereotype on IAT measures.

One method that has been developed to address this shortcoming of IAT measures is the Go-No-Go Association task (GNAT). The GNAT offers a way to measure gender stereotypes for math separately from gender stereotypes for other domains such as reading or language. This is done, for example, by asking participants to push a button if, for example, math is paired with male but not if math is paired with female, or by providing them with the opposite task – press a button when math is paried with female, but not when it is paired with male (Nosek & Banaji, 2001; Steffens & Jelenec, 2011). A study using the GNAT with 9th graders found that females did not show an implicit gender stereotype for math but did show an implicit gender stereotype for language. Unfortunately, the GNAT is not nearly as reliable as IATs, and a child-friendly GNAT has not yet been developed.

Explicit Measure Variations. Explicit math-gender stereotype measures also vary. As previously mentioned, some studies ask children about the math ability of males and females and others ask them about whether males or females like math more. It is possible that young children have a greater understanding of questions about liking math than questions about math ability, related to the development of children's conceptions of ability. Explicit measures also vary as to whether they require a forced choice of male or female, or include an option to respond that there is no gender difference. Ambady et al.'s (2001) found that 75% of children in elementary and middle school responded that there is no difference, suggesting that giving the option of a "no difference" response can have a significant effect on findings.

Similar to implicit math-gender stereotypes, determining whether explicit responses actually reflect a math-gender stereotype or perhaps instead an own gender bias on the part of males requires comparing responses in two domains that are not subject to the same gender stereotype. For example, children could be asked questions about male versus female math ability/liking and their responses could be compared to those about male versus female reading ability/liking, a domain that is not stereotyped in favor of males (J. Steele, 2003; Steffens et al., 2010).

Relation to Math Outcomes. Math-gender stereotypes typically have negative effects on girls' identification with math and their math achievement but positive effects on boys' identification with math and math achievement (e.g., Ambady et al., 2001; Galdi et al., 2014; Huguet & Régner, 2007; 2009). Cvencek et al. (2015) made the powerful point that stereotypes can affect children's future academic goals and identities. For the most part, however, studies of young children's math-gender stereotypes have focused on the relation of these stereotypes to math achievement. It is certainly possible, however, that at relatively early ages, the math-gender stereotype begins to have broader effects on children's math interests, sense of belonging and their nascent career interests (see Master & Meltzoff, 2020 for review). In the following section, we focus on studies that have manipulated stereotype threat to address the relation of the math-gender stereotype to math achievement in young children.

Stereotype Threat Studies with Children. In a classic study with college students, Spencer et al. (1999) found that females scored lower than their male peers on a challenging math test when students were told that males typically outperform females on the test they were about to take. Moreover, the authors showed that this was even the case when no information about gender differences in performance was provided prior to the test. This effect is referred to as "stereotype threat" and is thought to increase anxiety, which compromises working memory resources that would otherwise be available to support high levels of performance on math assessments (see Schmader & Johns, 2003 for review; Spencer et al., 1999; Tomasetto, 2019). In contrast, when students were told there was no gender difference on the math test they were about to take, there was no gender difference in test performance. Interestingly, males sometimes experience a small "stereotype lift" when stereotypes are activated, performing better than when stereotypes are negated (e.g., Walton & Cohen, 2003).

Stereotype threat (ST) manipulations have been used to study the relation of math-gender stereotypes to math outcomes in young children, beginning as early as kindergarten. Here we explore when stereotype type threat effects emerge and whether they increase with age. One might expect that ST effects on math performance might be stronger at older than younger ages, based on Cultural Experiental Theory and evidence that both implicit and explicit math-gender stereotypes show developmental increases.

Ambady et al. (2001) gave Asian American girls in three age groups (kindergarten to 2nd grade, 3rd to 5th grade, 6th to 8th grade) a math test after priming a positively stereotyped identity (Asian), a negatively stereotyped identity (female), or neither identity (control condition). Girls in the youngest and oldest groups performed best after their ethnicity was primed and worst when their gender was primed, with those in the control group performing at an intermediate level. These findings mirror those found with college students in a study that used a similar paradigm (Shih et al., 1999). However, Ambady et al. (2001) found a different pattern for 3rd to 5th grade girls. Counter to stereotype threat, girls at this age performed significantly better when their gender was primed than in either of the other conditions. The authors speculate that children in these grades are particularly chauvinistic about their gender and thus do better when their gender is primed. In a second study, the researchers examined the effects of the math-gender stereotype on the math performance of Asian American boys in these same age groups. In the youngest and oldest groups, the boys performed better on a math test when either their gender or Asian identities were primed, both of which are positively stereotyped, compared to boys in the control condition. Broadly, these results are consistent with the math-gender stereotype decreasing girls' and increasing boys' math performance.

Another study utilized an arguably more potent way to activate the math-gender stereotype and also found that ST negatively affected the math performance of 6-year-old girls (Galdi et al., 2014). In the stereotype congruent condition, 6-year-old girls colored a picture of a boy correctly solving a calculation problem and a girl failing to do so; in the stereotype incongruent condition they colored a picture of a girl correctly solving a calculation problem and a boy failing to do so. There was also a control condition in which children colored a picture of a landscape. Girls in the stereotype congruent and control conditions showed an implicit math-gender stereotype, but those in the stereotype incongruent condition did not. Further, girls' math performance was lowest in the stereotype congruent condition and highest in the stereotype incongruent condition, and the effect of condition on math performance was mediated by girls' implicit math-gender stereotype regardless of their explicit stereotype endorsement.

Building on these findings, Neuville and Croizet (2007) showed that ST negatively affected the performance of 3rd grade girls on difficult (but not easy) math problems. These findings are consistent with ST effects shown with college students (Spencer et al., 1999), and with the theory that stereotypes are most likely to negatively affect performance on challenging problems because they lead to anxiety that depletes working memory resources that are needed to solve these problems (Schmader & Johns, 2003). These findings highlight the importance of considering the difficulty of the math task when examining the effects of ST effects.

An important question is whether ST negatively affects girls' math performance in ecologically valid classroom settings – not just in the lab. Huguet and Régner (2007; 2009) examined this question with 10- to 13-year-old students in France. Children were asked to study a complex design and then to draw it from memory. In the ST condition, children were told that this task was a geometry test, whereas those in the control condition were told that the same task was a drawing test. Girls performed significantly better in the drawing-labeled condition than in the geometry-labeled condition whereas boys' performance did not differ by condition. Moreover, boys performed better than girls in the geometry-labeled condition, but girls outperformed boys in the drawing-labeled condition. Consistent with C.M. Steele's (1997) claim that stereotype endorsement is not a precondition for ST effects, girls' explicit endorsement of the math-gender stereotype did not moderate these effects. Huguet & Regner (2007) also found that girls were negatively affected by ST when they were in a mixed gender classroom but not when they were in a classroom with only girls.

Muzzatti and Agnoli (2007) report condition (ST, Control) × gender interactions in older by not younger students. In one study, they found no gender difference in the math performance of 2nd to 4th graders in an ST condition versus a control condition, but did find a male advantage in math performance among 5th graders in the ST condition. A second study showed the condition by gender interaction for 8th graders but not 3rd or 5th graders

In contrast to these positive ST findings, in a series of studies, Ganley et al. (2013) found no evidence that ST negatively impacts 4th to 12th grade females' math performance, even though they focused on students who showed high identification with math and used challenging math tests as outcomes, which should have maximized the likelihood of finding ST effects (Spencer et al., 1999). Further, systematic reviews and meta-analyses have revealed weak ST effects in both children and adults (Stoet & Geary, 2012; Flore & Wicherts, 2015). Moreover, even when meta-analyses report significant ST effects, publication bias has been identified as a problem (Flore & Wicherts, 2015). These findings underscore the need for rigorous research using designs that are sufficiently powered and that measure likely moderators that are not assessed in many studies (e.g., degree of identification with math; difficult of the math assessment).

Stereotype Reactance. Stereotype reactance, a heightened motivation to disprove a stereotype, may contribute to the heterogeneity of findings in stereotype threat studies. Notably, 1st to 5th grade boys and girls in Singapore showed a positive relation between implicit (but not explicit) math-gender stereotypes and math achievement (Cvencek et al., 2015). While this positive association would be expected for boys because their group's math ability is positively stereotyped, it is surprising for girls because their group's math ability is negatively stereotyped. The unexpected finding for girls might reflect stereotype reactance, which has been found in older students in high achieving contexts (e.g., China; Tsui et al., 2011).

Conclusions. Children in elementary school consistently show implicit math-gender stereotypes. Although adults' implicit math-gender stereotypes are stronger than those of young children's, we lack information about *when* during development math-gender stereotypes become stronger. Longitudinal studies assessing implicit and explicit math-gender stereotypes as well as gender stereotypes about other academic domains would improve our understanding of the developmental trajectory of the math-gender stereotype as well as its domain specificity.

Implicit math-gender stereotypes have a stronger relation to math achievement than explicit math-gender stereotypes. The implicit math-gender stereotype is typically negatively related to girls' math test scores during elementary school, with some studies reporting this relation emerges by early elementary school, and others reporting that it does not emerge until 5th grade. Stereotype threat effects have been reported in some studies with young children, but meta-analyses and systematic reviews indicate that these effects are heterogeneous and may be subject to publication bias. Variations in results could be due to the methods used, for example the way that stereotypes were activated, the difficulty of the math tests given and/or to cultural factors. An interesting open question is why girls are able to achieve higher math grades than boys despite the presence of the math-gender stereotype. There is evidence that math anxiety is most detrimental in solving complex problems, which are likely to be encountered on high stakes tests (Namkung et al., 2019). Thus, the anxiety related to the math-gender stereotype may be most detrimental in these testing situations. Moreover, other factors (e.g., tests focusing on learned materials favoring girls, tests focusing on novel material favoring boys) may enable girls to achieve higher grades than boys (Kimball, 1989).

Although work on the development of math-gender stereotypes has been carried out in various cultural contexts, we have limited understanding of how culture moderates the math-gender stereotype and its relation to achievement-related outcomes. Moreover, we also need to increase our understanding of how within-culture factors such as race, ethnicity, and SES may moderate the development and effects of this stereotype. Relatedly, we need to examine the development and effects of math-gender stereotype in children who are high and low in their math achievement. Finally, we need more research to understand how different stereotypes combine to affect individuals who identify with multiple groups whose math abilities are negatively stereotyped (e.g., female and underrepresented minority) or are differently stereotyped (e.g., female and Asian).

Relation of math-gender stereotypes to other math attitudes

Identification with Math, Math Self-Concept, and Math Anxiety. Consistent with Heider's Cognitive Balance Theory (Greenwald et al., 2002; Heider, 1946), Cvencek et al. (2011, 2015) found that gender identity, math-gender stereotypes, and identification with math tend to align. Specifically, a boy who believes me = boy and math = my gender is likely to identify with math (me = math). In contrast, a girl who believes me = girl and math ≠ my gender is likely to not identify with math (me ≠ math). Cvencek et al.'s (2011, 2015) findings suggest that gender identity emerges prior to math-gender stereotypes, which in turn emerge before self-identity with math. Thus, the math-gender stereotype may influence boys' stronger and girls' weaker identification with math.

There is also evidence that the math-gender stereotype is linked to the gender difference in math self-concept (favoring boys), with some studies reporting this relation as early as mid-elementary school (Kurtz-Costes et al., 2008; Passolunghi et al., 2014) and others reporting it in adolescents (Jacobs, 1991; Passolunghi et al., 2014; Wolff, 2021). Further, adolescent boys' and girls' explicit math-gender stereotype positively predicts their math anxiety (Casad et al., 2015). The unexpected positive relation in boys may be connected to the added pressure of being expected to perform well in math and the relation in girls may be connected to a lowered sense of their belonging in math, and to anxiety about confirming the stereotype. To our knowledge, there is no evidence of the reverse relation—that math anxiety predicts math-gender stereotypes. Clearly, more work, particularly with young children is needed, to understand the longitudinal relations between math-gender stereotypes and other math attitudes, and to determine whether these relations are causal. Existing correlational evidence is consistent with our hypothesis that the math-gender stereotype may be a hub attitude that affects self-relevant math attitudes such as math self-concept and math anxiety, but longitudinal and experimental studies are needed to test this hypothesis.

Field-Specific Ability Beliefs (FAB) Hypothesis. Children's math-gender stereotypes may be related to or even undergirded by the belief that success in certain fields, including math, requires brilliance, referred to as the Field Specific Ability Beliefs (FAB) hypothesis (Leslie et al., 2015; Meyer et al., 2015). Experts and laypeople believe that "a special aptitude that cannot be taught" is required for success in certain fields, including math and math-intensive fields. Importantly, fields for which people think brilliance is required for success have fewer women earning doctoral degrees and the kernel of this link appears to emerge early in development.

Developmental studies indicate that a brilliance-gender stereotype, like the math-gender stereotype, emerges by early elementary school. In a series of four studies, Bian et al. (2017) tested 5- to 7-year-olds from middle-income, predominantly white families, and found that 6- and 7-year-old girls were less likely than boys to regard members of their own-gender as "really, really smart" and were less likely to be interested in a game for "children who are really, really smart", even though they were just as interested as boys in a game for "children who try really, really hard." Moreover, the relation between gender and interest in a game for smart children was mediated by girls' stereotyped beliefs about brilliance and gender. Thus, the male = brilliance stereotype emerges early and at about the same time as the math-gender stereotype, consistent with the possibility that these stereotypes are related. An important question is whether the male = brilliance stereotype, and the male = math stereotype account for unique or shared variance in girls' math achievement, math attitudes, and sense of belonging in math and STEM fields.

Conclusions. Gender differences in children's endorsement of implicit math-gender stereotypes precede gender differences in children's identification with math. Interestingly, the explicit math-gender stereotype predicts adolescent boys' math self-concept and both adolescent boys' and girls' math anxiety. The math-gender stereotype may also be related to the male = brilliance stereotype, given that math is a field that is thought to require brilliance and girls show lower interest than boys in a game that is for really, really smart kids. Thus, girls' belief that success in math requires brilliance might be related and even be causally linked to their math-gender stereotype.

Key socializers

Expectancy-Value Theory provides a framework for examining key socializers' beliefs about how good their sons/daughters and male/female students are at math. As reviewed in the Math Self-Concept section, key socializers believe that boys are more competent in math than girls and that math is more valuable for boys than girls, beliefs that are related to children's math self-concepts (Eccles et al., 2000; Herbert & Stipek, 2005; Lindberg et al., 2008; Lummis & Stevenson, 1990; Stoet et al., 2016). Here, we focus on how key socializers' math-gender stereotypes relate to their beliefs about the math competence of the girls and boys they interact with. We also review research examining the consequences of key socializers' math-gender stereotypes and child-specific math competence beliefs for children's math achievement-related outcomes, and whether these consequences differ depending on children's age.

Parents' Math-Gender Stereotypes. Several studies show a connection between parents' math or math/science gender stereotypes and children's math self-concept (Jacobs, 1991; Kurtz-Costes et al, 2008; Tiedemann, 2000b). In a study of adolescents, Jacobs (1991) found that mothers' and fathers' math-gender stereotypes interact with the sex of their child to predict their beliefs about their children's math ability and future math success, which in turn predict their children's math self-concept. Further, both adolescents' math self-concept and parents' math-gender stereotypes directly predicted adolescents' math grades. Strikingly, having parents read a stereotype consistent report about differences between males' and females' math ability led them to change their beliefs about their own child's math ability in stereotypic ways (Jacobs & Eccles, 1985).

In a study carried out in Germany, Tiedemann (2000b) extended this work to parents and younger children in 3rd and 4th grade. As Jacobs (1991) found for adolescents, Tiedemann (2000b) found that mothers' and fathers' math-gender stereotypes predicted their gender-biased perceptions of their own children's math ability – higher for boys and lower for girls – and these ability perceptions predicted their children's math self-concept. One notable developmental difference in the intergenerational relations of parents' math-genderstereotypes is that for adolescents, parents' math-gender stereotypes were related to their children's math grades (Jacobs, 1991), but this was not the case for elementary school children (Tiedemann, 2000b). These findings suggest that intervening on parents' math-gender stereotypes and math expectations may be more effective when children are younger, before parents' math attitudes have undermined children's math achievement over many years.

Further, over a broad range of child ages, parents tend to attribute their sons' math success to talent and their daughters' math success to effort (Eccles et al., 1990; Parsons et al., 1982; Yee & Eccles, 1988). Additionally, mothers of 2nd, 3rd and 5th graders encouraged their sons, more than their daughters, to participate in STEM-related activities, even though boys and girls do not differ in their responses to this encouragement (Simpkins et al., 2005).

Mothers' and fathers' math-gender stereotypes have also been found to relate to their intrusive homework support with their 5th to 8th grade children. A study carried out by Bhanot and Jovanovic (2005) showed that even though boys received more intrusive support than girls, girls were more sensitive to this kind of support in the math domain. Moreover, parents' intrusive math homework support mediated the negative relation between parents' math-gender stereotypes and girls' lower math self-concept.

On a more positive note, parents who reject the math-gender stereotype decrease the susceptibility of their daughters' math performance to stereotype threat. Priming the gender of kindergarten to 2nd grade girls led to a decrease in their math performance compared to a control group, but this was not the case for girls whose mothers strongly rejected the math-gender stereotype (Tomasetto et al., 2011). Consistent with findings suggesting that female role models have positive effects on girls' math and STEM outcomes, it was specifically mothers' rejection of the stereotype that led to this buffering (see Halpern et al., 2007 for review).

Teachers' Math-Gender Stereotypes. Similar findings have been found in studies examining the relation of teachers' math-gender stereotypes to their perceptions of students' math ability. Third and 4th grade teachers in Germany who reported math-gender stereotypes rated their male students' math ability more highly than their female students', even though there was not a gender differences in math grades (Tiedemann, 2002). Importantly, there were no such gender-biased differences in the ratings of teachers who did not endorse the math-gender stereotype. Moreover, the relation of teachers' math-gender stereotypes to their gender-stereotypic ratings of their students' math ability was moderated by students' level of math achievement. That is, teachers' math-gender stereotypes were connected to their assessments of the math abilities of average and low achieving girls and boys, but not high achieving girls and boys. This suggests that girls' high achievement in math can override their teachers' math-gender stereotypes, likely because stereotypes tend to come into play to reduce uncertainty about ambiguous data (e.g., Campbell, 1967).

Like parents, teachers also make different attributions about the math successes and failures of girls and boys. For example, 1st grade teachers were likely to attribute boys' success in math to talent and attribute their failures in math to lack of effort, whereas they were likely to attribute girls' success in math to effort and their failures to lack of ability (Fennema et al., 1990). Further, elementary school teachers in Germany rated average achieving boys as more talented in math than average achieving girls. They also reported that girls would benefit less from effort than boys, even though girls' and boys' math achievement did not differ (Tiedemann, 2000a).

Of note, a recent study, carried out in Germany with secondary school girls indicates that the math-gender stereotypes of peers affect girls' math self-concept. In this study, the math-gender stereotypes of other students in the classroom as well as girls' own math-gender stereotypes, predicted girls' math-self concept (Wolff, 2021). An interesting question is whether these peer effects are more prevalent in classrooms where teachers hold a math-gender stereotype.

Differences in Key Socializers' Math-Related Interactions with Boys and Girls. While it is certainly possible that gender differences in key socializers' interactions with young children could reflect evocative effects of children's interests, there is evidence that key socializers' math support is biased by their gender-stereotypic beliefs (Eccles et al. 1990; Jacobs & Eccles, 1992; Gunderson, Ramirez, Levine et al., 2012). Some studies suggest that teachers' math-gender stereotypes lead them to call on boys in math class more than girls (Becker, 1981; Eccles et al., 1983; Lubienski et al., 2013). This is likely to be consequential for math outcomes as Jacobs and Wigfield (1989) found that having fewer opportunities to respond is associated with a decrease in females' interest in taking more math courses (for reviews see Gunderson, Ramirez, Levine et al., 2012; Li, 1999; Master and Meltzoff, 2020). Additionally, Lindberg et al. (2008) found that mothers who embraced traditional gender roles (e.g., thinking education is more important for boys than girls), provided their daughters with more math content and more assistance than they provided their sons, even though there was no gender difference in children's math knowledge. This was not true of mothers who were more egalitarian in their gender beliefs. If girls find the math help provided by their more traditional mothers as indicative of their mothers' low perceptions of their math ability, it could undermine their math self-concept as well as their interest in math, based on findings showing the negative effects of parents' intrusive math homework help (Silinskas & Kikas, 2019).

Key socializers may also convey their math-gender stereotypes to the children they interact with through gender-related differences in talk and play, which over time may influence children's interests. For example, parents engage in more spatial talk and spatial play with their preschool boys than girls (Pruden & Levine, 2017; Levine et al., 2012). Such differences may result from parents' stereotypes about children's math and spatial skills; and may be consequential for children's long-term math achievement, given close associations between spatial and math skills (Mix et al., 2016, 2017) and the relation of spatial skills to STEM achievement and career paths (Wai et al., 2009).

Likely, based on parents' different behaviors towards boys and girls, children perceive them as holding a math-gender stereotype, and this has consequences for boys' and girls' own math-gender stereotype and math self-concept. Kurtz-Costes et al. (2008) found that 6th and 8th grade boys' perception of adults' math/science gender stereotypes led to stronger endorsement of the stereotype and a more positive math/science self-concept, relations that were not present in 4th grade boys, even though they perceived adults as holding this stereotype. In contrast, girls' perception of adults' math/science gender stereotype had effects at younger ages and were negatively related to their own math/sciene gender stereotype (4th graders) and to their math/science self-concept (6th graders; Kurtz-Costes et al., 2008).

Conclusions. Key socializers' math-gender stereotypes predict their gender-biased perceptions of their children's/students'mathabilities and their attributions about boys' and girls' math successes and failures. They also predict their differential encouragement of boys' versus girls' math engagement. Moreover, key socializers' math-gender stereotypes predict children's math self-concept and math-gender stereotype as early as elementary school and the math achievement of middle and high school students. A question for future research is how key socializers' math-gender stereotypes affect their math interactions with girls and boys, and whether intervening on adults' stereotypes would make these interactions more equitable, would reduce children's math-gender stereotypes, and would increase girls' math self-concepts as well as their math and STEM outcomes.

Interventions

Several different approaches hold promise for alleviating the negative effects of math-gender stereotypes on math achievement-related outcomes. These interventions can reduce math-gender stereotypes and mitigate the negative effects of these stereotypes on females' math and STEM outcomes. However, there has been little intervention work of this sort with young children. As described below, this is an area in need of systematic research.

Mindset Interventions. Several studies have examined whether mindset interventions mitigate the negative effects of math-gender stereotypes. Growth mindsets are hypothesized to help females overcome the negative effects of math-gender stereotypes because this stereotype is fundamentally a belief that math abilities are fixed by virtue of gender group (Aronson et al., 2002; Dweck,1999; Good et al., 2003). In support of this possibility, as reviewed in the Mindset section, Good et al. (2003) found that a mindset intervention with 7th grade girls from lower SES backgrounds raised their math performance and eliminated the male advantage that was present in the control group. Another study, involving college students taking a calculus course, showed that when females perceived their math environment as endorsing a growth mindset about math this increased their sense of belonging in math, their math grades, and their intentions to pursue math in the future, even when they perceived their math environment as endorsing the math-gender stereotype (Good et al., 2012).

To date, little work has addressed whether having a growth mindset protects young girls from the negative effects of math-gender stereotypes and increases their sense of belonging in math. One study, however, suggests that increasing sense of belonging could be an important target for interventions with young children (Master et al., 2017). In this study, preschool children completed a task (either math or spatial) as part of a minimal group (intervention condition) or individually (control condition). Children in the minimal group condition persisted longer, completed more of the math or spatial task, and reported higher self-efficacy and interest in the task than children in the control group. This suggests that group math activities could increase children's sense of belonging in math, which in turn could increase their STEM motivation and achievement. As described below, this approach may be particularly helpful in increasing girls' math interests given findings that framing STEM careers as more collaborative and communal increases females' STEM interests (Diekman et al., 2010, 2011). An open question is whether young children's early awareness of the math-gender stereotype is already starting to erode girls' sense of belonging in math, and whether this is particularly the case for girls with a fixed mindset.

Providing Substantive Feedback. As reviewed in the Mindset/Implicit Theory section, providing children with feedback about their performance in the form of process praise rather than person praise. is effective in supporting children's math motivation, persistence and achievement (Gunderson, Sorhagen, et al., 2018; Mueller & Dweck, 1998). Further, criticisms that focus on learning and strategies for improvement support children's math outcomes (e.g., Gunderson, Donnellan, et al., 2018; Heyman & Dweck, 1998). Importantly, the pattern of positive and negative feedback that teachers more commonly provide to girls than boys may undermine their math achievement (e.g., Dweck et al., 1978). Further, the feedback young girls receive in math contexts may be particularly influential, given their lower math self-concept, higher math anxiety, greater tendency to adopt helpless responses in the face of failure, and the fact that they are stereotyped to have low math ability (see Halpern et al., 2007 for review).

Creating Environments that Increase Females' STEM Interests. Research by Diekman et al. (2010, 2011) suggests that the higher endorsement of communal goals by women and the belief that STEM careers do not fulfill communal goals may contribute to the underrepresentation of women in STEM. Building on females' communal goals goals and framing STEM careers as more collaborative compared to more individualistic increased female college students' interest in pursuing these careers and did not lessen male students' interest in these careers (Diekman et al., 2011). Thus, highlighting the communal aspects of STEM work—that it is collaborative, involves helping people, and benefits humanity—may increase females' interest in STEM careers. An important question for future research is whether this kind of framing would increase young girls' interest in STEM.

Role Models. The use of counter-stereotypic role models to increase females' interest in STEM is motivated by theories positing that individuals' gender role stereotypes, behaviors, and aspirations are influenced by their observations of the roles typically filled by males and females in their society (Bigler & Liben, 2006; Eagly & Wood, 2011; Bem, 1981). Based on these theories, studies have examined the effects of exposing individuals to counter-stereotypical gender role models and have found that this type of intervention can change gender stereotypes as well as self-efficacy beliefs, career aspirations and STEM performance in adolescents and adults (e.g., Diekman & Eagly, 2000; see Olsson & Martiny, 2018 for review).

A successful intervention with 12- to 16-year-old girls in Spain evaluated an intervention that involved having female STEM leaders visit participating classrooms. Results showed a pretest to posttest increase in girls' math enjoyment, perceptions of the importance of math, expectations of success in math, and STEM aspirations, and a decrease in girls' math-gender stereotype. The reduction of the math-gender stereotype was strongly related to the importance girls placed on doing well in math. Further, the intervention was more effective if participants perceived the sessions to be highly counter-stereotypical with respect to STEM in that they emphasized the importance of communication, teamwork, and social skills in STEM, in line with Diekman et al.'s findings (2010, 2011). Consistent with these results, several role model interventions utilizing random assignment of participants into intervention and control groups found positive effects of counter-stereotypic role models and mentors on STEM outcomes of adolescents and adults (Stoeger et al., 2016; Stout et al., 2011; see Van den Hurk et al., 2019 for review).

Counter-stereotypic role model interventions are not always successful, however, and their success depends on several factors, including the extent to which individuals identify with the role model and the extent to which they view the achievements of the role model as attainable (Olsson & Martiny, 2018). A study that involved having 6th and 7th graders highlights this kind of limitation. In this study, students read about STEM or non-STEM role models who were either highly feminine or not. Findings showed that for girls who did not already identify with STEM, highly feminine STEM role models were de-motivating because this combination was viewed as unattainable (Betz & Sekaquaptewa, 2012). Relatedly, undergraduate women induced to hold a growth mindset about a leadership ability were more likely to benefit from a counter-stereotypical role model than undergraduate women induced to hold an entity mindset about this ability (Hoyt et al., 2012). This is likely because holding a growth mindset about the targeted ability leads them to believe it is possible for them to attain the success of the role model.

A few studies have examined the effects of gender counter-stereotypical role models in preschool and elementary school children. Whereas role model interventions with older adolescents and college students may help retain students who are already pursuing STEM interests and inspire others to explore STEM as a possible career path, interventions with young students mainly fall into the latter category. Many of these studies involve exposing young children to role models through literature or commercials, but some involve in-person role models (e.g., Nhundu, 2007; Tozzo & Golub, 1990; Trepanier-Street & Romatowski, 1999; see Abad & Pruden, 2013 for review of storybook interventions; and Olsson & Martiny, 2018 for review of interventions that have focused on young children). The duration of interventions also varies from one exposure to counter-stereotypic information to more intensive multi-year interventions that are incorporated into school curricula (e.g., Ashton, 1983; Nhundu, 2007; Tozzo & Golub, 1990; Trepanier-Street & Romatowski, 1999).

Perhaps the most intensive role model intervention to date was a three-year study of 4th to 7th grade students in Zimbabwe. The intervention involved exposing children in the intervention condition to biographies of inspiring females with gender-counter-stereotypical careers and children in the control condition to traditional educational materials. The books in the intervention emphasized the message that anybody can do a job they like if they get training and become skillful. Even though there were some issues with randomization, it is important to review this study due to its long-term nature and interesting findings. The results showed that girls in the intervention condition showed significant shifts in their career interests compared to pretest and were more interested than those in the control condition in careers that are typically stereotyped to be for males. However, the intervention did not eliminate gender-stereotypic beliefs about family responsibilities (i.e., that once women marry, they should give up their careers). These findings suggest that in order to have sustained, meaningful effects on females' career choices, interventions need to address broad gender-stereotypic beliefs, including beliefs about family responsibilities and career beliefs. Moreover, interventions are likely to have greater success if they address gender stereotypes not only with girls, but also with boys, families, and the broader community that girls are a part of (Olsson & Martiny, 2018).

Emphasizing the Relation of Occupations to Skills. Another approach to broadening young children's career interests involves highlighting that careers depend on skills and interests rather than gender. In one such study, 6- to 11-year-old children in the intervention group received one week of 20-minute lessons emphasizing the importance of interests and skills, rather than gender, in occupations (e.g., a construction worker has to like building things and know how to operate a bulldozer). In contrast, children in the control group received lessons that focused on what people in particular occupations do (Bigler & Liben, 1990). At post-test, children in the intervention condition showed less gender stereotyping of careers than the children in the control group, including careers not covered in the lessons. However, this change in gender stereotyping was not accompanied by a change in children's own career aspirations. Rather, most children in both conditions chose a gender-stereotypic career.

These findings make sense given the relatively short duration of the intervention and the massive amount of gender-stereotypic information children receive from socializers, peers, the media, and society in general about the roles of males and females. Thus, these findings highlight an important limitation of interventions that focus on increasing children's interests in counter-stereotypic careers: They may decrease the math-gender stereotype but not change children's own career aspirations. This suggests that in order to broaden children's career interests beyond those that are gender-stereotypic, including their interests in math and STEM, interventions need to be sustained and to involve not only children, but key socializers and the broader community.

Intergenerational. Related to taking a more comprehensive approach to increasing girls' STEM interests, there have been successful intergenerational approaches to increasing the STEM interests of high school students, both males and females. For example, Harackiewicz et al. (2012) conducted an experiment in which parents and their high school students were randomized into an intervention group that received brochures and an associated website about the utility of math and science for careers and everyday activities or were placed in a business as usual control condition. The intervention increased parents' utility-value of STEM courses and their conversations with their children about STEM courses. Most importantly, their children took more advanced and elective STEM courses in high school. Further, the intervention increased students' utility-value for STEM courses, an effect that was mediated by increases in parents' utility-value for STEM courses and students' reports of STEM conversations with parents. An important question for future research is whether an adapted form of this kind of intervention would be effective for younger children and whether it could be used to reduce parents' math-gender stereotypes, their gender-related support of STEM, and the negative effects of these beliefs and behaviors on children's math-related outcomes.

Conclusions. A variety of different intervention approaches hold promise for addressing adolescents' and adults' math-gender stereotypes. However, we need more research examining the effectiveness of these approaches with young children, a time when children's math-gender stereotypes may be more malleable. Moreover, we have little information about whether positive short-term effects that result from interventions are sustained over time. It is likely that to have long-term positive effects on girls' math attitudes and math achievement, interventions will need to be comprehensive, long-term, and start early, before their math-gender stereotypes have eroded their math achievement and interests.

What we know and questions for future research

To recap, we have seen that the math-gender stereotype emerges by early elementary school, particularly at the implicit level. Moreover, the implicit math-gender stereotype negatively predicts girls' math achievement by early elementary school, controlling for the explicit stereotype. Additionally, children's math-gender stereotypes are related to their math self-concepts by mid-elementary school, in a negative direction for girls and a positive direction for boys. Further, by adolescence, the math-gender stereotype is related to math anxiety (see EMAA model, Fig. 1). Research also shows that the math-gender stereotypes of parents and teachers are connected to children's math attitudes and math achievement, most likely through the different attributions that socializers make about girls' and boys' math abilities and the gender-related behaviors they engage in with children.

Our review also highlights critical avenues for future research. There are important questions about how cultural context moderates the development of math-gender stereotypes that are deserving of attention. The use of different measures to assess math-gender stereotypes makes it difficult to compare the results of studies carried out in different cultural contexts. Basic research that investigates how the same children respond to different measures would be helpful in interpreting inconsistent findings and the relation of cultural contexts to math-gender stereotypes.

Moreover, we currently lack information about whether starting to intervene on the math-gender stereotype at early ages is an effective way to reduce the negative effects of this stereotype. Indeed, research is needed to increase our understanding of the kinds of interventions that are most effective at particular developmental time points, and whether this varies depending on cultural and demographic differences. It is likely that long-term interventions are needed in order to counteract the massive amount of stereotype congruent information children receive from multiple sources. Relatedly, we need to develop and test more comprehensive, intergenerational and community-based interventions to determine whether this kind of approach results in more positive outcomes than child-focused interventions.

General discussion

Our final section highlights what we have learned and future directions concerning the development of math attitudes and their relation to children's math achievement In addition, we highlight what we have learned and future directions concerning the relations among key socializers' math attitudes, their math interactions with children, and children's math achievement and attitudes. Throughout, we tie our discussion to our proposed Early Math Achievement-Attitude model (EMAA model), which focuses on the *emergence* of math achievement-attitude relations, and is thus based, as much as is currently possible, on findings from studies of young children.

Relation of math attitudes and math achievement

By early elementary school, children's self-relevant and general math attitudes are associated with math achievement (Ambady et al., 2001; Gunderson, Park et al., 2018; Pantoja et al., 2020). Moreover, lagged correlational findings indicate that math achievement predicts math attitudes, including math anxiety, math self-concept, and achievement goals, more strongly than the reverse as is shown in the EMAA model (Ching et al., 2020; see Fig. 1). Thus, efforts to support early math learning—which typically focus on building math concepts and skills—may also be effective in building positive math attitudes. However, we need experiments that assess whether these relations are causal. For example, a potential experiment could compare the effects of a combined cognitive-affective intervention on the math achievement and math attitudes of young children to interventions that address only one of these components. Further, intervening early might be particularly effective, as young children's math attitudes are less closely linked to their math achievement than later in development, and thus negative links may be more malleable. Understanding why child math achievement is predictive of child math attitudes is also important, as there may be mechanisms, such as children's interpretation of their math achievement and their experience with key socializers during math activities, that explain the early emerging relation of math achievement to math attitudes.

In addition to the need for experiments that can provide evidence of causal links between math attitudes and math achievement, there are various other research directions that would enhance our current knowledge about the development of the math achievement * math attitude link. One topic that has received little attention is the stability of math attitudes over development. Although we know that math self-concept becomes more stable over time (Wigfield et al., 1997), longitudinal studies are needed to determine whether this is the case for other attitudes. Another important next step is to examine when children's math attitudes begin to predict not only math achievement, but also a wider range of math outcomes. One challenge to addressing this question is that until children are in high school, they typically do not make decisions about math course taking or career directions. However, young children's behaviors in math situations (e.g., math problem solving strategies, math study strategies, preference for challenging math, interest in math clubs and activities, and nascent career interests) may shed light on the scope of early math attitude * math behavior relations. Finally, research is needed to understand the development of math attitudes and their relation to math achievement in different cultural contexts, as well as in underrepresented minority groups, as most studies have used convenience samples which overrepesent people from Western, educated, industrialized, rich and democratic (WEIRD) backgrounds.

Relation of math attitudes to each other

Our understanding of math attitude * math achievement relations would be enhanced by characterizing constellations of math attitudes in young children, and how these constellations predict math achievement. Although many studies have examined the relation of one or a small set of math attitudes to math achievement, we are just beginning to understand how these math attitudes may influence each other and jointly predict young children's math achievement.

Existing findings raise the possibility that certain math attitudes, in particular math achievement goals (performance or learning) and math-gender stereotypes, serve as hub attitudes that have consequences for other math attitudes (e.g., math anxiety and math self-concept), as is shown in the EMAA model (see Fig. 1). In support of this possibility, achievement goals, which are an early emerging feature of motivational frameworks predict young children's math anxiety, but not the reverse. Further, math-gender stereotypes predict identification with math and math self- concept by early elementary school as well as math anxiety by adolescence. (Casad et al., 2015; Cvencek et al., 2011, 2015; Wigfield et al., 1997). However, more work, particularly with young children, is needed to test whether certain math attitudes serve as hub attitudes that lead to other math attitudes, either positive or negative. One way to test this, is to examine whether intervening and successfully improving an early math attitude such as achievement goals or the math-gender stereotype also changes math anxiety and math self-concept, and whether this transfer effect is stronger than the reverse approach (e.g., intervening on math anxiety may have a smaller effect on math achievement goals and math-gender stereotypes)

Another interesting research question concerns the relation between the math-gender stereotype and mindset. It is likely that math-gender stereotypes and mindset are related to each other because the math-gender stereotype is fundamentally a fixed view of math ability. That is, the stereotype that males are better at math than females, rests on the view that some groups have more fixed, biologically based math ability than other groups. Thus, those who exhibit the math-gender stereotype, either implicitly or explicitly, may be more likely to have a fixed mindset about math ability whereas those who do not exhibit the stereotype may be more likely to have a growth mindset about math ability. Another open question is how the math-gender stereotype relates to math performance versus learning goals. One possibility is that the math-gender stereotype is associated with girls' performance goals, since performing well may be viewed as a way to disprove the stereotype. To our knowledge the relations of these attitudes have not been systematically examined in children or adults.

Gender differences

During elementary school, boys are less math anxious and have higher math self-concepts than girls (Dowker et al., 2012;

Gunderson, Park et al., 2018). These mean-level gender differences in math anxiety and math self-concept suggest that math-gender stereotypes may play a role in shaping these math attitudes. Indeed, by early elementary school, girls and boys show implicit math-gender stereotypes, and these stereotypes are associated with girls' lower identification with math and boy's higher identification with math.

While some studies show significant gender differences in mindset and others do not, studies that find a significant difference consistently show the same pattern: boys have a stronger growth mindset than girls. This is unfortunate given that having a growth mindset has been found to buffer the negative effects of the math-gender stereotype on females' math achievement and sense of belonging in math, at least for college students. An important unanswered question is whether the gender difference in mindset is stronger for mindset about math ability than for mindset about ability in other academic domains.

Studies have also examined whether there are gender differences in math attitude * math achievement relations. Existing research shows that the math self-concept * math achievement relation is similar for boys and girls. There are inconsistent findings with respect to gender differences in the math anxiety * math achievement relation, with some studies finding a stronger relation in boys, others finding a stronger relation in girls, and others finding no gender differences in this relation. One consistent finding is that the math-gender stereotype, and particularly the implicit math-gender stereotype, is negatively related to girls' but not boys' math achievement. An important next step involves increasing our understanding of the factors that lead to the development of gender differences in math attitudes and their relations to math achievement-related outcomes.

Key socializers

We reviewed three types of math attitudes key socializers hold: general (math-gender stereotypes, mindsets), self-relevant (math anxiety, math self-concept), and child-specific (socializers' expectations and value of math for their child or student). We found that key socializers' math attitudes are related to each other, as is the case for children. For example, parents with high math anxiety have lower expectations and value of their children's math achievement (Schaeffer et al., 2018). Additionally, teachers with high math anxiety are less confident in their ability to teach math effectively (Richland et al., 2020), and those with a fixed mindset are likely to adopt performance oriented rather than mastery-oriented teaching goals (Park et al., 2016). Further, both teachers' and parents' math-gender stereotypes predict their biased child-specific math beliefs, such that they think the girls they interact with are less competent in math than the boys they interact with, when there are no discernable gender differences in boys' versus girls' math abilities. Further, key socializers' math-gender stereotypes have been linked to differences in their math interactions with boys and girls.

Multiple studies have shown that parents' and teachers' math attitudes are predictors of children's math attitudes and math achievement. For example, key socializers' child-specific math beliefs predict children's math self-concept and math achievement. Further, teachers' fixed mindsets predict their performance oriented instructional practices, which in turn predict children's entity-oriented motivational frameworks. It is likely that the mechanism through which key socializers' math attitudes predict children's math attitudes and math achievement is through key socializers' behaviors, as is shown in the EMAA model (see Fig. 1). The relation of key socializers' early math engagement to children's math achievement has been consistently shown (e.g., Berkowitz et al., 2015; Gunderson & Levine, 2011; Levine et al., 2010; see EMAA model, Fig. 1). In addition, key socializers' math attitudes predict their interactions with their children and students (e.g., Berkowitz et al., 2021; del Río et al., 2017; Park et al., 2016; Wigfield et al., 2006, 2015).

There are several important research directions that would enrich our current knowledge about the relation of key socializers' math attitudes and behaviors and children's math achievement and attitudes. Most current studies focus on either parent–child or teacher child interactions, but not both. Moreover, studies focusing on parents, mainly focus on mothers. We would gain important information by widening the lens of research to examine how the attitudes and behaviors of mothers, fathers, teachers, and other caregivers, as well as siblings and peers, jointly influence children's math outcomes. For example, is having one key socializer with negative math attitudes detrimental to children's math achievement and math attitudes, or is having one key socializer with positive math attitudes protective of children's math achievement and math attitudes?

An important research direction involves obtaining more detailed information about the mechanisms that underlie the relation of key socializers' math attitudes and young children's math outcomes. Observing and coding key socializer-child math interactions can inform our understanding of these mechanisms by providing detailed, qualitative information that goes beyond what can be obtained through questionnaires or even through experiments that provide evidence that intervening on socializers' math attitudes (e.g., their math anxiety) leads to children's higher achievement. Examining key socializer-child interactions can provide answers to questions such as: Does the socializer focus on outcomes and/or process during math problem solving when providing homework help? Does the socializer prompt the child in order to promote mastery, or do they provide intrusive support during math interactions? How does the socializer praise and criticize the child? Does the socializer communicate negative feelings about math through verbal or nonverbal cues? With this kind of information, researchers will be in a stronger position to identify the practices that are most predictive of positive and negative math outcomes for children, which is critical to the design of effective interventions.

Another open question is whether children's attitudes and achievement in math—compared to other domains—are particularly sensitive to key socializers' behaviors. This may be the case, as children's math performance is regularly evaluated based on the correctness of their answers. Related to this focus on answers, existing research suggests that some young children focus more on outcomes than on the process of learning. Because of the objective nature of the answers to math problems, an outcome focus may lead to the development of negative math attitudes, especially for children who face challenges in learning math. Relatedly, another important avenue for research involves examining the role that children themselves play in key socializers' child-specific math attitudes and behaviors.

Interventions

Related to the role of key socializers in the development of children's math attitudes and math achievement, intergenerational interventions that involve parents and their children have yielded promising results. For example, parents' child-specific math attitudes are malleable, particularly their expectations and value of math for their children. Moreover, improving these child-specific attitudes in turn may improve parent–child math interactions. Another kind of intergenerational approach involves supporting parent–child math interactions (e.g., by providing fun, low-stakes math materials) which in turn can increase socializers' child-specific math attitudes (Schaeffer et al., 2018; see Fig. 1), and enhance children's math learning. Effective interventions will likely involve co-development with families, which will lead to approaches that build on current practices that could or already include math (e.g., Civil & Bernier, 2006). Whether combining these approaches—addressing parents' child-specific math beliefs and addressing their math-related behaviors—yields more positive results than an approach that focuses on math beliefs or math behaviors alone is a question that deserves attention.

Child-focused interventions may also be effective as math attitudes may be particularly malleable at young ages. Home and school math experiences that are enjoyable, that focus on the process of learning rather than the outcome, and that build children's math skills might be particularly effective in improving young children's math attitudes. It is also possible that addressing "hub" math attitudes (e.g., achievement goals, stereotypes) might have beneficial effects on other math attitudes (see EMAA model, Fig. 1). However, the effectiveness of interventions appear to vary with development. Notably, affective interventions that have improved adolescents' math achievement, such as expressive writing prior to taking a math test, have been shown to harm young children's math achievement. An unanswered question is whether interventions that focus on both cognitive and affective aspects of math attitudes may be particularly effective in improving math outcomes. Research with adolescents, has shown that interventions that focus on beliefs as well as the control of stress may be effective and help with transfer of benefits (Jamieson et al., 2018; Yeager et al., 2016). An important next step is to examine whether such combined approaches are particularly beneficial for math outcomes, and for what age groups.

Finally, we need to develop and evaluate the effectiveness of interventions on long term math outcomes. Interventions that have sustained effects on children's math attitudes and math achievement will likely require addressing math learning and math attitudes throughout development using evidenced-basedmethods that are tuned to children's development and cultural context. Importantly, basic research on the development of math knowledge and attitudes needs to proceed hand in hand with intervention work. Basic research can enrich our understanding of the mechanisms that lead to the development of virtuous or vicious relations of math achievement and math attitudes, and can inform intervention research. In turn, the results of intervention studies are likely to raise new and important questions that will stimulate basic research. Focusing our attention on the early development of math achievement * math attitude relations in diverse populations, with the goal of promoting positive math attitudes and high math achievement for every child, holds promise for promoting math excellence, social equity, and innovations that can benefit society.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the National Science Foundation Science of Learning Collaborative Network Grant #1540741 to Susan C. Levine, and the Heising-Simons Foundation Development and Research in Early Mathematics Education (DREME) Network Grant #2018-0680 (support to Susan C. Levine); and the Overdeck Foundation and Thomas W. Sidlik and Rebecca Anne Boylan for their support of the Family Math Attitudes Project (support to Susan C. Levine). This work was supported by the National Science Foundation (GRFP-1144082/1746045 to Nancy Pantoja) and the Institute of Education Sciences at the University of Chicago, U.S. Department of Education through Grant Number R305B140048 at the University of Chicago (to Nancy Pantoja). We thank Mariana Sosa and Dania Smithstein for their support in preparing this manuscript.

References

Abad, C., & Pruden, S. M. (2013). Do storybooks really break children's gender stereotypes? *Frontiers in Psychology, 4*, 986. https://doi.org/10.3389/fpsyg.2013.00986

Ablard, K. E., & Mills, C. J. (1996). Implicit theories of intelligence and self-perceptions of academically talented adolescents and children. *Journal of Youth and Adolescence, 25*(2), 137–148. https://doi.org/10.1007/BF01537340

Ahmavaara, A., & Houston, D. M. (2007). The effects of selective schooling and self-concept on adolescents' academic aspiration: An examination of Dweck's self-theory. *British Journal of Educational Psychology, 77*(3), 613–632. https://doi.org/10.1348/000709906X120132

Ahmed, W., Minnaert, A., Kuyper, H., & van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning and Individual Differences, 22*(3), 385–389. https://doi.org/10.1016/j.lindif.2011.12.004

Allensworth, E. M., & Clark, K. (2020). High school GPAs and ACT scores as predictors of college completion: Examining assumptions about consistency across high schools. *Educational Researcher, 49*(3), 198–211. https://doi.org/10.3102/0013189X20902110

Ambady, N., Shih, M., Kim, A., & Pittinsky, T. L. (2001). Stereotype susceptibility in children: Effects of identity activation on quantitative performance. *Psychological Science, 12*(5), 385–390. https://doi.org/10.1111/1467-9280.00371

Arens, A. K., Frenzel, A. C., & Goetz, T. (2020). Self-concept and self-efficacy in math: Longitudinal interrelations and reciprocal linkages with achievement. *The Journal of Experimental Education, 1–19*. https://doi.org/10.1080/00220973.2020.1786347

Arens, A. K., Marsh, H. W., Craven, R. G., Yeung, A. S., Randhawa, E., & Hasselhorn, M. (2016). Math self-concept in preschool children: Structure, achievement relations, and generalizability across gender. *Early Childhood Research Quarterly, 36*, 391–403. https://doi.org/10.1016/j.ecresq.2015.12.024

Arens, A. K., Marsh, H. W., Pekrun, R., Lichtenfeld, S., Murayama, K., & vom Hofe, R. (2017). Math self-concept, grades, and achievement test scores: Long-term reciprocal effects across five waves and three achievement tracks. *Journal of Educational Psychology, 109*(5), 621–634. https://doi.org/10.1037/edu0000163

Arens, A. K., Yeung, A. S., Craven, R. G., & Hasselhorn, M. (2011). The twofold multidimensionality of academic self-concept: Domain specificity and separation between competence and affect components. *Journal of Educational Psychology, 103*(4), 970–981. https://doi.org/10.1037/a0025047

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology, 38*(2), 113–125. https://doi.org/10.1006/jesp.2001.1491

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. https://doi.org/10.1111/1467-8721.00196

Ashcraft, M. H., Krause, J. A., & Hopko, D. R. (2007). Is math anxiety a mathematical learning disability? In D. B. Berch, & M. M. M. Mazzocco (Eds.), *Why is math so hard for some children? The nature and origins of mathematical learning difficulties and disabilities* (pp. 329–348). Paul H. Brookes Publishing Co.

Ashton, E. (1983). Measures of play behavior: The influence of sex-role stereotyped children's books. *Sex Roles, 9*(1), 43–47. https://doi.org/10.1007/BF00303108

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2020). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin. Advance online publication., 147*(2), 134–168. https://doi.org/10.1037/bul0000307

Becker, J. R. (1981). Differential treatment of females and males in mathematics classes. *Journal for Research in Mathematics Education, 12*(1), 40–53. https://doi.org/10.5951/jresematheduc.12.1.0040

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail: Working memory and "choking under pressure" in math. *Psychological Science, 16*(2), 101–105. https://doi.org/10.1111/j.0956-7976.2005.00789.x

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences, 107*(5), 1860–1863. https://doi.org/10.1073/pnas.0910967107

Beilock, S. L., Rydell, R. J., & McConnell, A. R. (2007). Stereotype threat and working memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology: General, 136*(2), 256–276. https://doi.org/10.1037/0096-3445.136.2.256

Beilock, S. L., Schaeffer, M. W., & Rozek, C. S. (2017). Understanding and addressing performance anxiety. In A. J. Elliot, C. S. Dweck, & D. S. Yeager (Eds.), *Handbook of competence and motivation: Theory and application* ((2nd ed.,, pp. 155–172). Guilford Press.

Bem, S. L. (1981). Gender schema theory: A cognitive account of sex typing. *Psychological Review, 88*(4), 354–364. https://doi.org/10.1037/0033-295X.88.4.354

Bempechat, J., London, P., & Dweck, C. S. (1991). Children's conceptions of ability in major domains: An interview and experimental study. *Child Study Journal, 21*(1), 11–36.

Benenson, I., & Dweck, C. S. (1986). The development of train explanations and self-evaluation in the academic and social domains. *Child Development, 57*(5), 1179–1189. https://doi.org/10.2307/1130441

Berkowitz, T., Gibson, D., & Levine, S. C. (2021). Parents' math anxiety predicts early number talk with children. *Journal of Cognition and Development*.

Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Levine, S. C., & Beilock, S. L. (2015). Math at home adds up to achievement in school. *Science, 350*(6257), 196–198. https://doi.org/10.1126/science.aac7427

Betz, D. E., & Sekaquaptewa, D. (2012). My fair physicist? Feminine math and science role models demotivate young girls. *Social Psychological and Personality Science, 3*(6), 738–746. https://doi.org/10.1177/1948550612440735

Bhanot, R., & Jovanovic, J. (2005). Do parents' academic gender stereotypes influence whether they intrude on their children's homework? *Sex Roles, 52*(9–10), 597–607. https://doi.org/10.1007/s11199-005-3728-4

Bian, L., Leslie, S. J., & Cimpian, A. (2017). Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science, 355*(6323), 389–391. https://doi.org/10.1126/science.aah6524

Bigler, R. S., & Liben, L. S. (1990). The role of attitudes and interventions in gender-schematic processing. *Child Development, 61*(5), 1440–1452. https://doi.org/10.1111/cdev.1990.61.issue-510.1111/j.1467-8624.1990.tb02873.x

Bigler, R. S., & Liben, L. S. (2006). A developmental intergroup theory of social stereotypes and prejudice. In R. V. Kail (Ed.), Advances in child Development and behavior (Vol. 34, pp. 39-89). Elsevier. Doi: 10.1016/S0065-2407(06)80004-2.

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78*(1), 246–263. https://doi.org/10.1111/cdev.2007.78.issue-110.1111/j.1467-8624.2007.00995.x

Bleeker, M. M., & Jacobs, J. E. (2004). Achievement in math and science: Do mothers' beliefs matter 12 years later? *Journal of Educational Psychology, 96*(1), 97–109. https://doi.org/10.1037/0022-0663.96.1.97

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education, 17*(4), 369–386. https://doi.org/10.1080/09540250500145072

Boaler, J. O. (2013). Ability and mathematics: The mindset revolution that is reshaping education. *Forum, 55*(1), 143. https://doi.org/10.2304/forum10.2304/forum.2013.55.110.2304/forum.2013.55.1.143

Boaler, J. (2016). Mathematical Mindsets: Unleashing Students' Potential Through Creative Math, Inspiring Messages and Innovative Teaching. Jossey-Bass.

Brunyé, T. T., Mahoney, C. R., Giles, G. E., Rapp, D. N., Taylor, H. A., & Kanarek, R. B. (2013). Learning to relax: Evaluating four brief interventions for overcoming the negative emotions accompanying math anxiety. *Learning and Individual Differences, 27*, 1–7. https://doi.org/10.1016/j.lindif.2013.06.008

Burkley, M., Parker, J., Stermer, S. P., & Burkley, E. (2010). Trait beliefs that make women vulnerable to math disengagement. *Personality and Individual Differences, 48*(2), 234–238. https://doi.org/10.1016/j.paid.2009.09.002

Burnette, J. L., O'Boyle, E. H., VanEpps, E. M., Pollack, J. M., & Finkel, E. J. (2013). Mind-sets matter: A meta-analytic review of implicit theories and self-regulation. *Psychological Bulletin, 139*(3), 655–701. https://doi.org/10.1037/a0029531

Bursal, M., & Paznokas, L. (2006). Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics, 106*(4), 173–180. https://doi.org/10.1111/j.1949-8594.2006.tb18073.x

Cain, K. M., & Dweck, C. S. (1995). The relation between motivational patterns and achievement cognitions through the elementary school years. *Merrill-Palmer Quarterly, 41*(1), 25–52. https://www.jstor.org/stable/23087453.

Calsyn, R. J., & Kenny, D. A. (1977). Self-concept of ability and perceived evaluation of others: Cause or effect of academic achievement? *Journal of Educational Psychology, 69*(2), 136–145. https://doi.org/10.1037/0022-0663.69.2.136

Campbell, D. T. (1967). Stereotypes and the perception of group differences. *American Psychologist, 22*(10), 817–829. https://doi.org/10.1037/h0025079

Carey, E., Hill, F., Devine, A., & Szűcs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology, 6*, 1987. https://doi.org/10.3389/fpsyg.2015.01987

Carey, E., Hill, F., Devine, A., & Szűcs, D. (2017). The modified abbreviated math anxiety scale: A valid and reliable instrument for use with children. *Frontiers in Psychology, 8*, 11. https://doi.org/10.3389/fpsyg.2017.00011

Cargnelutti, E., Tomasetto, C., & Passolunghi, M. C. (2017). How is anxiety related to math performance in young students? A longitudinal study of Grade 2 to Grade 3 children. *Cognition and Emotion, 31*(4), 755–764. https://doi.org/10.1080/02699931.2016.1147421

Casad, B. J., Hale, P., & Wachs, F. L. (2015). Parent-child math anxiety and math-gender stereotypes predict adolescents' math education outcomes. *Frontiers in Psychology, 6*, 1597. https://doi.org/10.3389/fpsyg.2015.01597

Chen, S. K., Yeh, Y. C., Hwang, F. M., & Lin, S. S. (2013). The relationship between academic self-concept and achievement: A multicohort–multioccasion study. *Learning and Individual Differences, 23*, 172–178. https://doi.org/10.1016/j.lindif.2012.07.021

Cheng, Z. J., & Hau, K. T. (2003). Are intelligence and personality changeable? Generality of Chinese students' beliefs across various personal attributes and age groups. *Personality and Individual Differences, 34*(5), 731–748. https://doi.org/10.1016/S0191-8869(02)00030-2

Cheng, Y. L., & Mix, K. S. (2014). Spatial training improves children's mathematics ability. *Journal of Cognition and Development, 15*(1), 2–11. https://doi.org/10.1080/15248372.2012.725186

Ching, B. H. H. (2017). Mathematics anxiety and working memory: Longitudinal associations with mathematical performance in Chinese children. *Contemporary Educational Psychology, 51*, 99–113. https://doi.org/10.1016/j.cedpsych.2017.06.006

Ching, B.-H., Kong, K. H. C., Wu, H. X., & Chen, T. T. (2020). Examining the Reciprocal Relations of Mathematics Anxiety to Quantitative Reasoning and Number Knowledge in Chinese Children. *Contemporary Educational Psychology, 63*, 101919. https://doi.org/10.1016/j.cedpsych.2020.101919

Chinn, S. (2012). Beliefs, anxiety, and avoiding failure in mathematics. *Child Development Research, 2012*, 1–8. https://doi.org/10.1155/2012/396071

Choe, K. W., Jenifer, J. B., Rozek, C. S., Berman, M. G., & Beilock, S. L. (2019). Calculated avoidance: Math anxiety predicts math avoidance in effort-based decision-making. *Science Advances, 5*(11), eaay1062. https://doi.org/10.1126/sciadv.aay1062

Cimpian, A., Arce, H. M. C., Markman, E. M., & Dweck, C. S. (2007). Subtle linguistic cues affect children's motivation. *Psychological Science, 18*(4), 314–316. https://doi.org/10.1111/j.1467-9280.2007.01896.x

Cimpian, J. R., Lubienski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open, 2*(4), 2–19. https://doi.org/10.1177/2332858416673617

Civil, M., & Bernier, E. (2006). Exploring images of parental participation in mathematics education: Challenges and possibilities. *Mathematical Thinking and Learning, 8*(3), 309–330. https://doi.org/10.1207/s15327833mtl0803_6

Claro, S., Paunesku, D., & Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. *Proceedings of the National Academy of Sciences, 113*(31), 8664–8668. https://doi.org/10.1073/pnas.1608207113

Corpus, J. H., & Lepper, M. R. (2007). The effects of person versus performance praise on children's motivation: Gender and age as moderating factors. *Educational Psychology, 27*(4), 487–508. https://doi.org/10.1080/01443410601159852

Cvencek, D., Kapur, M., & Meltzoff, A. N. (2015). Math achievement, stereotypes, and math self-concepts among elementary-school students in Singapore. *Learning and Instruction, 39*, 1–10. https://doi.org/10.1016/j.learninstruc.2015.04.002

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math–gender stereotypes in elementary school children. *Child Development, 82*(3), 766–779. https://doi.org/10.1111/j.1467-8624.2010.01529.x

Cvencek, D., Paz-Albo, J., Master, A., Llácer, C. V. H., Hervás-Escobar, A., & Meltzoff, A. N. (2020). Math is for me: A field intervention to strengthen math self-concepts in Spanish-speaking 3rd grade children. *Frontiers in Psychology, 11*, Article 593995.

Dapp, L. C., & Roebers, C. (2018). Self-concept in kindergarten and first grade children: A longitudinal study on structure, development, and relation to achievement. *Psychology, 9*(7), 1605–1629. https://doi.org/10.4236/psych.2018.97097

Degol, J. L., Wang, M. T., Zhang, Y., & Allerton, J. (2018). Do growth mindsets in math benefit females? Identifying pathways between gender, mindset, and motivation. *Journal of Youth and Adolescence, 47*(5), 976–990. https://doi.org/10.1007/s10964-017-0739-8

del Río, M. F., Strasser, K., Cvencek, D., Susperreguy, M. I., & Meltzoff, A. N. (2019). Chilean kindergarten children's beliefs about mathematics: Family matters. *Developmental Psychology, 55*(4), 687–702. https://doi.org/10.1037/dev0000658

del Río, M. F., Susperreguy, M. I., Strasser, K., Cvencek, D., Iturra, C., Gallardo, I., & Meltzoff, A. N. (2021). Early Sources of Children's Math Achievement in Chile: The Role of Parental Beliefs and Feelings about Math. *Early Education and Development, 32*(5), 637–652. https://doi.org/10.1080/10409289.2020.1799617

del Río, M. F., Susperreguy, M. I., Strasser, K., & Salinas, V. (2017). Distinct influences of mothers and fathers on kindergartners' numeracy performance: The role of math anxiety, home numeracy practices, and numeracy expectations. *Early Education and Development, 28*(8), 939–955. https://doi.org/10.1080/10409289.2017.1331662

Devine, P. G. (1989). Stereotypes and prejudice: Their automatic and controlled components. *Journal of Personality and Social Psychology, 56*(1), 5–18. https://doi.org/10.1037/0022-3514.56.1.5

Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions, 8*, 33. https://doi.org/10.1186/1744-9081-8-33

Devine, A., Hill, F., Carey, E., & Szűcs, D. (2017). Cognitive and emotional math problems largely dissociate: Prevalence of developmental dyscalculia and mathematics anxiety. *Journal of Educational Psychology, 110*, 431–444. https://doi.org/10.1037/edu0000222

Dew, K. H., & Galassi, J. P. (1983). Mathematics anxiety: Some basic issues. *Journal of Counseling Psychology, 30*(3), 443–446. https://doi.org/10.1037/0022-0167.30.3.443

Dietrich, J. F., Huber, S., Moeller, K., & Klein, E. (2015). The influence of math anxiety on symbolic and non-symbolic magnitude processing. *Frontiers in Psychology, 6*, 1621. https://doi.org/10.3389/fpsyg.2015.01621

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21*(8), 1051–1057. https://doi.org/10.1177/0956797610377342

Diekman, A. B., Clark, E. K., Johnston, A. M., Brown, E. R., & Steinberg, M. (2011). Malleability in communal goals and beliefs influences attraction to stem careers: Evidence for a goal congruity perspective. *Journal of Personality and Social Psychology, 101*(5), 902–918. https://doi.org/10.1037/a0025199

Diekman, A. B., & Eagly, A. H. (2000). Stereotypes as dynamic constructs: Women and men of the past, present, and future. *Personality and Social Psychology Bulletin, 26*(10), 1171–1188. https://doi.org/10.1177/0146167200262001

DiStefano, M., O'Brien, B., Storozuk, A., Ramirez, G., & Maloney, E. A. (2020). Exploring math anxious parents' emotional experience surrounding math homework-help. *International Journal of Educational Research, 99*, 10156. https://doi.org/10.1016/j.ijer.2019.101526

Dowker, A., Cheriton, O., Horton, R., & Mark, W. (2019). Relationships between attitudes and performance in young children's mathematics. *Educational Studies in Mathematics, 100*(3), 211–230. https://doi.org/10.1007/s10649-019-9880-5

Dowker, A., Bennett, K., & Smith, L. (2012). Attitudes to mathematics in primary school children. *Child Development Research, 2012*, 1–8. https://doi.org/10.1155/2012/124939

Droege, K. L., & Stipek, D. J. (1993). Children's use of dispositions to predict classmates' behavior. *Developmental Psychology, 29*(4), 646–654. https://doi.org/10.1037/0012-1649.29.4.646

Duckworth, A. L., & Seligman, M. E. (2006). Self-discipline gives girls the edge: Gender in self-discipline, grades, and achievement test scores. *Journal of Educational Psychology, 98*(1), 198–208. https://doi.org/10.1037/0022-0663.98.1.198

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist, 41*(10), 1040–1048. https://doi.org/10.1037/0003-066X.41.10.1040

Dweck, C. S. (1999). *Self-theories: Their Role in Personality, Motivation, and Development*. Psychology Press.

Dweck, C. S. (2002). The development of ability conceptions. In A. Wigfield, & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 57–88). Academic Press. https://doi.org/10.1016/B978-012750053-9/50005-X.

Dweck, C. S. (2003). Ability conceptions, motivation and development. In L. Smith, C. Rogers, & P. Tomlinson (Eds.), BJEP Monograph series II, No. 2—Development and motivation. The British Psychological Society.

Dweck, C. S. (2007). The perils and promises of praise. *Educational Leadership, 12*, 34–39.

Dweck, C. S. (2008). *Mindset: The New Psychology of Success*. Random House Digital Inc.

Dweck, C. S., Davidson, W., Nelson, S., & Enna, B. (1978). Sex differences in learned helplessness: II. The contingencies of evaluative feedback in the classroom and III. An experimental analysis. *Developmental Psychology, 14*(3), 268–276. https://doi.org/10.1037/0012-1649.14.3.268

Dweck, C. S., & Elliott, E. S. (1983). Achievement motivation. In E. M. Hetherington (Ed.), Handbook of Child Psychology: Socialization, personality, and social development (4th ed., Vol. 4., pp. 643-691). Wiley.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256–273. https://doi.org/10.1037/0033-295X.95.2.256

Dweck, C. S., & Yeager, D. S. (2019). Mindsets: A view from two eras. *Perspectives on Psychological Science, 14*(3), 481–496. https://doi.org/10.1177/1745691618804166

Eagly, A. H., & Wood, W. (2011). Feminism and the evolution of sex differences and similarities. *Sex Roles, 64*(9-10), 758–767. https://doi.org/10.1007/s11199-011-9949-9

Eccles (Parsons), J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), Expectancies, values, and academic behaviors (pp. 75–146). Freeman.
Eccles, J. S., Freedman-Doan, C., Frome, P., Jacobs, J., & Yoon, K. S. (2000). Gender-role socialization in the family: A longitudinal approach. The Developmental Social Psychology of Gender, 333-360. Lawrence Erlbaum Associates Publishers.
Eccles, J. S., Jacobs, J. E., & Harold, R. D. (1990). Gender role stereotypes, expectancy effects, and parents' socialization of gender differences. *Journal of Social Issues, 46*(2), 183–201. https://doi.org/10.1111/j.1540-4560.1990.tb01929.x
Eccles, J. S., Lord, S., & Midgley, C. (1991). What are we doing to early adolescents? The impact of educational contexts on early adolescents. *American Journal of Education, 99*(4), 521–542. https://doi.org/10.1086/443996
Eccles, J. S., Midgley, C., & Adler, T. R. (1984). Grade-related changes in the school environment: Effects on achievement motivation. *The Development of Achievement Motivation, 3*, 283–331.
Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109–132. https://doi.org/10.1146/annurev.psych.53.100901.135153
Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61*, 101859. https://doi.org/10.1016/j.cedpsych.2020.101859
Eccles, J., Wigfield, A., Harold, R. D., & Blumenfeld, P. (1993). Age and gender differences in children's self-and task perceptions during elementary school. *Child Development, 64*(3), 830–847. https://doi.org/10.1111/cdev.1993.64.issue-310.1111/j.1467-8624.1993.tb02946.x
Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin, 136*(1), 103–127. https://doi.org/10.1037/a0018053
Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement at the intersection of gender and ethnicity. *Psychology of Women Quarterly, 37*(3), 293–309. https://doi.org/10.1177/0361684313480694
Erturan, S., & Jansen, B. (2015). An investigation of boys' and girls' emotional experience of math, their math performance, and the relation between these variables. *European Journal of Psychology of Education, 30*(4), 421–435. https://doi.org/10.1007/s10212-015-0248-7
Fennema, E., Peterson, P. L., Carpenter, T. P., & Lubinski, C. A. (1990). Teachers' attributions and beliefs about girls, boys, and mathematics. *Educational Studies in Mathematics, 21*(1), 55–69. https://doi.org/10.1007/BF00311015
Ferla, J., Valcke, M., & Cai, Y. (2009). Academic self-efficacy and academic self-concept: Reconsidering structural relationships. *Learning and Individual Differences, 19*(4), 499–505. https://doi.org/10.1016/j.lindif.2009.05.004
Felson, R. B., & Trudeau, L. (1991). Gender differences in mathematics performance. *Social Psychology Quarterly, 54*(2), 113–126. https://doi.org/10.2307/2786930
Flore, P. C., & Wicherts, J. M. (2015). Does stereotype threat influence performance of girls in stereotyped domains? A meta-analysis. *Journal of School Psychology, 53*(1), 25–44.
Foley, A. E., Herts, J. B., Borgonovi, F., Guerriero, S., Levine, S. C., & Beilock, S. L. (2017). The math anxiety-performance link: A global phenomenon. *Current Directions in Psychological Science, 26*(1), 52–58. https://doi.org/10.1177/0963721416672463
Folmer, A. S., Cole, D. A., Sigal, A. B., Benbow, L. D., Satterwhite, L. F., Swygert, K. E., & Ciesla, J. A. (2008). Age-related changes in children's understanding of effort and ability: Implications for attribution theory and motivation. *Journal of Experimental Child Psychology, 99*(2), 114–134. https://doi.org/10.1016/j.jecp.2007.09.003
Fredricks, J. A., & Eccles, J. S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology, 38*(4), 519–533. https://doi.org/10.1037/0012-1649.38.4.519
Frenzel, A. C., Pekrun, R., & Goetz, T. (2007). Perceived learning environment and students' emotional experiences: A multilevel analysis of mathematics classrooms. *Learning and Instruction, 17*(5), 478–493. https://doi.org/10.1016/j.learninstruc.2007.09.001
Frey, K. S., & Ruble, D. N. (1985). What children say when the teacher is not around: Conflicting goals in social comparison and performance assessment in the classroom. *Journal of Personality and Social Psychology, 48*(3), 550. https://doi.org/10.1037/0022-3514.48.3.550
Friedrich, A., Flunger, B., Nagengast, B., Jonkmann, K., & Trautwein, U. (2015). Pygmalion effects in the classroom: Teacher expectancy effects on students' math achievement. *Contemporary Educational Psychology, 41*, 1–12. https://doi.org/10.1016/j.cedpsych.2014.10.006
Fuhs, M., Farran, D. C., Meador, D., & Norvell, J. (June 2012). Classroom activities and organization: Comparing tools of the mind to control classrooms. In D. C. Farran (Chair), Developing Self-Regulation in Preschool Classrooms: Results from Research on the Tools of the Mind Prekindergarten Curriculum [Symposium] Biennial Meeting of the Head Start Research Conference, Washington, DC.
Galdi, S., Cadinu, M., & Tomasetto, C. (2014). The roots of stereotype threat: When automatic associations disrupt girls' math performance. *Child Development, 85*(1), 250–263. https://doi.org/10.1111/cdev.2014.85.issue-110.1111/cdev.12128
Ganley, C. M., & Lubienski, S. T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences, 47*, 182–193. https://doi.org/10.1016/j.lindif.2016.01.002
Ganley, C. M., Mingle, L. A., Ryan, A. M., Ryan, K., Vasilyeva, M., & Perry, M. (2013). An examination of stereotype threat effects on girls' mathematics performance. *Developmental Psychology, 49*(10), 1886–1897. https://doi.org/10.1037/a0031412
Geary, D. C., Hoard, M. K., Nugent, L., Chu, F., Scofield, J. E., & Ferguson Hibbard, D. (2019). Sex differences in mathematics anxiety and attitudes: Concurrent and longitudinal relations to mathematical competence. *Journal of Educational Psychology, 111*(8), 1447–1461. https://doi.org/10.1037/edu0000355
Gelman, S. A., Heyman, G. D., & Legare, C. H. (2007). Developmental changes in the coherence of essentialist beliefs about psychological characteristics. *Child Development, 78*(3), 757–774. https://doi.org/10.1111/cdev.2007.78.issue-310.1111/j.1467-8624.2007.01031.x
Gonida, E., Kiosseoglou, G., & Leondari, A. (2006). Implicit theories of intelligence, perceived academic competence, and school achievement: testing alternative models. *The American Journal of Psychology, 119*(2), 223–238. https://doi.org/10.2307/20445336
Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology, 24*(6), 645–662. https://doi.org/10.1016/j.appdev.2003.09.002
Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology, 102*(4), 700–717. https://doi.org/10.1037/a0026659
Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & Mellott, D. S. (2002). A unified theory of implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review, 109*(1), 3. https://doi.org/10.1037/0033-295X.109.1.3
Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: The implicit association test. *Journal of Personality and Social Psychology, 74*(6), 1464–1480. https://doi.org/10.1037/0022-3514.74.6.1464
Greenwald, A. G., Nosek, B. J., & Banaji, M. J. (2003). Understanding and using the Implicit Association Test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology, 85*(2), 197–216. https://doi.org/10.1037/0022-3514.85.2.197
Greenwald, A. G., Poehlman, T. A., Uhlmann, E. L., & Banaji, M. R. (2009). Understanding and using the Implicit Association Test: III. Meta-analysis of predictive validity. *Journal of Personality and Social Psychology, 97*(1), 17–41. https://doi.org/10.1037/a0015575
Gregg, A. P., Seibt, B., & Banaji, M. R. (2006). Easier done than undone: Asymmetry in the malleability of implicit preferences. *Journal of personality and social psychology, 90*(1), 1. https://doi.org/10.1037/0022-3514.90.1.1
Gresham, G. (2008). Mathematics anxiety and mathematics teacher efficacy in elementary pre-service teachers. *Teaching Education, 19*(3), 171–184. https://doi.org/10.1080/10476210802250133
Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and math. *Science Magazine, 320*(5880), 1164–1165. https://doi.org/10.1126/science.1154094
Gunderson, E. A., Donnellan, M. B., Robins, R. W., & Trzesniewski, K. H. (2018). The specificity of parenting effects: Differential relations of parent praise and criticism to children's theories of intelligence and learning goals. *Journal of Experimental Child Psychology, 173*, 116–135. https://doi.org/10.1016/j.jecp.2018.03.015

Gunderson, E. A., Gripshover, S. J., Romero, C., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2013). Parent praise to 1-to 3-year-olds predicts children's motivational frameworks 5 years later. *Child Development, 84*(5), 1526–1541. https://doi.org/10.1111/cdev.12064

Gunderson, E. A., Hamdan, N., Sorhagen, N. S., & D'Esterre, A. P. (2017). Who needs innate ability to succeed in math and literacy? Academic-domain-specific theories of intelligence about peers versus adults. *Developmental Psychology, 53*(6), 1188–1205. https://doi.org/10.1037/dev0000282

Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number talk count more than others: Relations between parents' input and children's cardinal-number knowledge. *Developmental Science, 14*(5), 1021–1032. https://doi.org/10.1111/j.1467-7687.2011.01050.x

Gunderson, E. A., Park, D., Maloney, E. A., Beilock, S. L., & Levine, S. C. (2018). Reciprocal relations among motivational frameworks, math anxiety, and math achievement in early elementary school. *Journal of Cognition and Development, 19*(1), 21–46. https://doi.org/10.1080/15248372.2017.1421538

Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2012). The relation between spatial skill and early number knowledge: The role of the linear number line. *Developmental Psychology, 48*(5), 1229–1241. https://doi.org/10.1037/a0027433

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3-4), 153–166. https://doi.org/10.1007/s11199-011-9996-2

Gunderson, E. A., Sorhagen, N. S., Gripshover, S. J., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2018). Parent praise to toddlers predicts fourth grade academic achievement via children's incremental mindsets. *Developmental Psychology, 54*(3), 397–409. https://doi.org/10.1037/dev0000444

Haimovitz, K., & Dweck, C. S. (2016). What predicts children's fixed and growth intelligence mind- sets? Not their parents' views of intelligence but their parents' views of failure. *Psychological Science, 27*(6), 859–869. https://doi.org/10.1177/0956797616639727

Haimovitz, K., Wormington, S. V., & Corpus, J. H. (2011). Dangerous mindsets: How beliefs about intelligence predict motivational change. *Learning and Individual Differences, 21*(6), 747–752. https://doi.org/10.1016/j.lindif.2011.09.002

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J. R., & Wentzel, K. (2007). Encouraging girls in math and science. *IES National Center for Education Research Practice Guide.* http://ies.ed.gov/ncer/pubs/practiceguides/20072003.asp.

Hamamura, T. (2012). Power distance predicts gender differences in math performance across societies. *Social Psychological and Personality Science, 3*(5), 545–548. https://doi.org/10.1177/1948550611429191

Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science, 23*(8), 899–906. https://doi.org/10.1177/0956797611435530

Harari, R. R., Vukovic, R. K., & Bailey, S. P. (2013). Mathematics anxiety in young children: An exploratory study. *The Journal of Experimental Education, 81*(4), 538–555. https://doi.org/10.1080/00220973.2012.727888

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*(1), 33–46. https://doi.org/10.5951/jresematheduc.21.1.0033

Heider, F. (1946). Attitudes and cognitive organization. *The Journal of Psychology, 21*(1), 107–112. https://doi.org/10.1080/00223980.1946.9917275

Helmke, A., & van Aken, M. A. (1995). The causal ordering of academic achievement and self-concept of ability during elementary school: A longitudinal study. *Journal of Educational Psychology, 87*(4), 624–637. https://doi.org/10.1037/0022-0663.87.4.624

Henderlong, J., & Lepper, M. R. (2002). The effects of praise on children's intrinsic motivation: A review and synthesis. *Psychological Bulletin, 128*(5), 774–795. https://doi.org/10.1037/0033-2909.128.5.774

Henderlong Corpus, J., & Lepper, M. R. (2007). The effects of person versus performance praise on children's motivation: Gender and age as moderating factors. *Educational Psychology, 27*(4), 487–508. https://doi.org/10.1080/01443410601159852

Herbert, J., & Stipek, D. (2005). The emergence of gender differences in children's perceptions of their academic competence. *Journal of Applied Developmental Psychology, 26*(3), 276–295. https://doi.org/10.1016/j.appdev.2005.02.007

Herts, J. B., Beilock, S. L., & Levine, S. C. (2019). The role of parents' and teachers' math anxiety in children's math learning and attitudes. In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: What is known and what is still to be understood* (pp. 190–210). Routledge.

Herts, J., & Levine, S. (2020). Gender and math development. Oxford Research Encyclopedia of Education. Doi: 10.1093/acrefore/9780190264093.013.1186.

Heyder, A., Weidinger, A. F., Cimpian, A., & Steinmayr, R. (2020). Teachers' belief that math requires innate ability predicts lower intrinsic motivation among low-achieving students. *Learning and Instruction, 65*, 101220. https://doi.org/10.1016/j.learninstruc.2019.101220

Heyman, G. D., & Dweck, C. S. (1998). Children's thinking about traits: Implications for judgments of the self and others. *Child Development, 69*(2), 391–403. https://doi.org/10.1111/j.1467-8624.1998.tb06197.x

Heyman, G. D., Dweck, C. S., & Cain, K. M. (1992). Young children's vulnerability to self-blame and helplessness: Relationship to beliefs about goodness. *Child Development, 63*(2), 401–415. https://doi.org/10.1111/cdev.1992.63.issue-210.1111/j.1467-8624.1992.tb01636.x

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences, 48*, 45–53. https://doi.org/10.1016/j.lindif.2016.02.006

Hong, Y. Y., Chiu, C. Y., Dweck, C. S., Lin, D. M. S., & Wan, W. (1999). Implicit theories, attributions, and coping: A meaning system approach. *Journal of Personality and Social Psychology, 77*(3), 588–599. https://doi.org/10.1037/0022-3514.77.3.588

Hoyt, C. L., Burnette, J. L., & Innella, A. N. (2012). I can do that: The impact of implicit theories on leadership role model effectiveness. *Personality and Social Psychology Bulletin, 38*(2), 257–268. https://doi.org/10.1177/0146167211427922

Huang, X., Zhang, J., & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: The gender moderating effect. *European Journal of Psychology of Education, 34*(3), 621–640. https://doi.org/10.1007/s10212-018-0403-z

Huguet, P., & Régner, I. (2007). Stereotype threat among schoolgirls in quasi-ordinary classroom circumstances. *Journal of Educational Psychology, 99*(3), 545–560. https://doi.org/10.1037/0022-0663.99.3.545

Huguet, P., & Régner, R. (2009). Counter-stereotypic beliefs in math do not protect school girls from stereotype threat. *Journal of Experimental Social Psychology, 45*(4), 1024–1027. https://doi.org/10.1016/j.jesp.2009.04.029

Hwang, N., Reyes, M., & Eccles, J. S. (2019). Who holds a fixed mindset and whom does it harm in mathematics? *Youth & Society, 51*(2), 247–267. https://doi.org/10.1177/0044118X16670058

Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist, 60*(6), 581–592. https://doi.org/10.1037/0003-066X.60.6.581

Hyde, J. S., Fennema, E., & Lamon, S. J. (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin, 107*(2), 139–155. https://doi.org/10.1037/0033-2909.107.2.139

Hyde, J. S., Fennema, E., Ryan, M., Frost, L. A., & Hopp, C. (1990). Gender comparisons of mathematics attitudes and affect: A meta-analysis. *Psychology of Women Quarterly, 14*(3), 299–324. https://doi.org/10.1111/j.1471-6402.1990.tb00022.x

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494–495. https://doi.org/10.1126/science:1160364

Hyde, J. S., & Mertz, J. E. (2009). Gender, culture, and mathematics performance. *Proceedings of the National Academy of Sciences, 106*(22), 8801–8807. https://doi.org/10.1073/pnas.0901265106

Jameson, M. M. (2013). The development and validation of the Children's Anxiety in Math Scale. *Journal of Psychoeducational Assessment, 31*(4), 391–395. https://doi.org/10.1177/0734282912470131

Jameson, M. M. (2014). Contextual factors related to math anxiety in second-grade children. *The Journal of Experimental Education, 82*(4), 518–536. https://doi.org/10.1080/00220973.2013.813367

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: An integrated model. *Anxiety, Stress, & Coping, 31*(3), 245–261.

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology, 46*(1), 208–212. https://doi.org/10.1016/j.jesp.2009.08.015

Jamieson, J. P., Peters, B. J., Greenwood, E. J., & Altose, A. J. (2016). Reappraising stress arousal improves performance and reduces evaluation anxiety in classroom exam situations. *Social Psychological and Personality Science, 7*(6), 579–587. https://doi.org/10.1177/1948550616644656

Jacobs, J. E. (1991). Influence of gender stereotypes on parent and child mathematics attitudes. *Journal of Educational Psychology, 83*(4), 518–527. https://doi.org/10.1037/0022-0663.83.4.518
Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned? *New Directions for Child and Adolescent Development, 2005*(110), 85–94. https://doi.org/10.1002/(ISSN)1534-868710.1002/cd.v2005:11010.1002/cd.151
Jacobs, J. E., & Eccles, J. S. (1985). Gender differences in math ability: The impact of media reports on parents. *Educational Researcher, 14*(3), 20–25. https://doi.org/10.3102/0013189X014003020
Jacobs, J. E., & Eccles, J. S. (1992). The impact of mothers' gender-role stereotypic beliefs on mothers' and children's ability perceptions. *Journal of Personality and Social Psychology, 63*(6), 932–944. https://doi.org/10.1037/0022-3514.63.6.932
Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development, 73*(2), 509–527. https://doi.org/10.1111/cdev.2002.73.issue-210.1111/1467-8624.00421
Jacobs, J. E., & Wigfield, A. (1989). Sex equity in mathematics and science education: Research-policy links. *Educational Psychology Review, 1*(1), 39–56. https://doi.org/10.1007/BF01326549
Jenßen, L., Hosoya, G., Jegodtka, A., Eilerts, K., Eid, M., & Blömeke, S. (2020). Effects of early childhood teachers' mathematics anxiety on the development of children's mathematical competencies. In O. Zlatkin-Troitschanskaia, H.A. Pant, M. Toepper, & C. Lautenbach (Eds.), Student learning in German higher education (pp. 141-162). Springer VS. Doi: 10.1007/978-3-658-27886-1.
Jenifer, J.B., Choe, K.W., Rozek, C.S., Berman, M.G., & Beilock, S.L. (in prep). Gender and effort-based decision-making: A gap in math-specific effort avoidance. Manuscript in preparation.
Jenifer, J.B*., Rozek, C.S*., Levine, S.C., Beilock, S.L. (under review). Effort(less) exam preparation: Math anxiety predicts the avoidance of effortful study strategies. Manuscript submitted for publication.
Jerrim, J., & Schoon, I. (2014). Do teenagers want to become scientists? A comparison of gender differences in attitudes toward science, career expectations, and academic skill across 29 countries. In I. Schoon, & J. S. Eccles (Eds.), *Gender differences in aspirations and attainment: A life course perspective* (pp. 203–223). Cambridge University Press.
Jordan, N. C., Kaplan, D., Nabors Olah, L., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77*(1), 153–175. https://doi.org/10.1111/cdev.2006.77.issue-110.1111/j.1467-8624.2006.00862.x
Justicia-Galiano, M. J., Martín-Puga, M. E., Linares, R., & Pelegrina, S. (2017). Math anxiety and math performance in children: The mediating roles of working memory and math self-concept. *British Journal of Educational Psychology, 87*(4), 573–589. https://doi.org/10.1111/bjep.12165
Kamins, M. L., & Dweck, C. S. (1999). Person versus process praise and criticism: Implications for contingent self-worth and coping. *Developmental Psychology, 35*(3), 835–847. https://doi.org/10.1037/0012-1649.35.3.835
Kaskens, J., Segers, E., Goei, S. L., van Luit, J. E. H., & Verhoeven, L. (2020). Impact of children's math self-concept, math self-efficacy, math anxiety, and teacher competencies on math development. *Teaching and Teacher Education, 94*, 103096. https://doi.org/10.1016/j.tate.2020.103096
Kersey, A. J., Braham, E. J., Csumitta, K. D., Libertus, M. E., & Cantlon, J. F. (2018). No intrinsic gender differences in children's earliest numerical abilities. *NPJ Science of Learning, 3*(1), 1–10. https://doi.org/10.1038/s41539-018-0028-7
Kersey, A. J., Csumitta, K. D., & Cantlon, J. F. (2019). Gender similarities in the brain during mathematics development. *NPJ Science of Learning, 4*(1), 1–7. https://doi.org/10.1038/s41539-019-0057-x
Kiefer, A. K., & Sekaquaptewa, D. (2007). Implicit stereotypes, gender identification, and math-related outcomes: A prospective study of female college students. *Psychological Science, 18*(1), 13–18. https://doi.org/10.1111/j.1467-9280.2007.01841.x
Killen, M., McGlothlin, H., & Henning, A. (2008). Explicit judgments and implicit bias: A developmental perspective. In S. R. Levy & M. Killen (Eds.), Intergroup attitudes and relations in childhood through adulthood (pp. 126–145). Oxford University Press.
Kimball, M. M. (1989). A new perspective on women's math achievement. *Psychological Bulletin, 105*(2), 198–214. https://doi.org/10.1037/0033-2909.105.2.198
Kinlaw, C. R., & Kurtz-Costes, B. (2007). Children's theories of intelligence: Beliefs, goals, and motivation in the elementary years. *The Journal of General Psychology, 134*(3), 295–311. https://doi.org/10.3200/GENP.134.3.295-312
Krinzinger, H., Kaufmann, L., & Willmes, K. (2009). Math anxiety and math ability in early primary school years. *Journal of Psychoeducational Assessment, 27*(3), 206–225. https://doi.org/10.1177/0734282908330583
Kurtz-Costes, B., Rowley, S. J., Harris-Britt, A., & Woods, T. A. (2008). Gender stereotypes about mathematics and science and self-perceptions of ability in late childhood and early adolescence. *Merrill-Palmer Quarterly, 54*(3), 386–409. https://www.jstor.org/stable/23096251.
Kyttälä, M., & Björn, P. M. (2010). Prior mathematics achievement, cognitive appraisals and anxiety as predictors of Finnish students' later mathematics performance and career orientation. *Educational Psychology, 30*(4), 431–448. https://doi.org/10.1080/01443411003724491
Lam, S. F., Yim, P. S., & Ng, Y. L. (2008). Is effort praise motivational? The role of beliefs in the effort–ability relationship. *Contemporary Educational Psychology, 33*(4), 694–710. https://doi.org/10.1016/j.cedpsych.2008.01.005
Lazarides, R., Dicke, A. L., Rubach, C., & Eccles, J. S. (2020). Profiles of motivational beliefs in math: Exploring their development, relations to student-perceived classroom characteristics, and impact on future career aspirations and choices. *Journal of Educational Psychology, 112*(1), 70–92. https://doi.org/10.1037/edu0000368
Lazarides, R., Dietrich, J., & Taskinen, P. H. (2019). Stability and change in students' motivational profiles in mathematics classrooms: The role of perceived teaching. *Teaching and Teacher Education, 79*, 164–175. https://doi.org/10.1016/j.tate.2018.12.016
Lee, C. Y., & Kung, H. Y. (2018). Math self-concept and mathematics achievement: Examining gender variation and reciprocal relations among junior high school students in Taiwan. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(4), 1239–1252. https://doi.org/10.29333/ejmste/82535
Lee, J. (2009). Universals and specifics of math self-concept, math self-efficacy, and math anxiety across 41 PISA 2003 participating countries. *Learning and Individual Differences, 19*(3), 355–365. https://doi.org/10.1016/j.lindif.2008.10.009
Leslie, S. J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science, 347*(6219), 262–265. https://doi.org/10.1126/science.1261375
Levine, S. C., Foley, A., Lourenco, S., Ehrlich, S., & Ratliff, K. (2016). Sex differences in spatial cognition: Advancing the conversation. *WIREs, 7*(2), 127–155.
Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial ability. *Developmental Psychology, 35*, 940–949.
Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early puzzle play: A predictor of preschoolers' spatial transformation skill. *Developmental Psychology, 48*(2), 530. https://doi.org/10.1037/a0025913
Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology, 46*(5), 1309–1319. https://doi.org/10.1037/a0019671
Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: A review. *Educational Research, 41*(1), 63–76. https://doi.org/10.1080/0013188990410106
Licht, B. G., & Dweck, C. S. (1984). Determinants of academic achievement: The interaction of children's achievement orientations with skill area. *Developmental Psychology, 20*(4), 628–636. https://doi.org/10.1037/0012-1649.20.4.628
Lindberg, S. M., Hyde, J. S., & Hirsch, L. M. (2008). Gender and mother-child interactions during mathematics homework: The importance of individual differences. *Merrill-Palmer Quarterly, 54*(2), 232–255. https://doi.org/10.1353/mpq.2008.0017
Liu, O. L. (2009). An investigation of factors affecting gender differences in standardized math performance: Results from US and Hong Kong 15-year-olds. *International Journal of Testing, 9*(3), 215–237. https://doi.org/10.1080/15305050903106875
Lohbeck, A., Grube, D., & Moschner, B. (2017). Academic self-concept and causal attributions for success and failure amongst elementary school children. *International Journal of Early Years Education, 25*(2), 190–203. https://doi.org/10.1080/09669760.2017.1301806
Lubienski, S. T., Robinson, J. P., Crance, C. C., & Ganley, C. M. (2013). Girls' and boys' mathematics achievement, affect, and experiences: Findings from the ECLS-K. *Journal for Research in Mathematics Education, 44*(4), 634–645. https://doi.org/10.5951/jresematheduc.44.4.634
Lummis, M., & Stevenson, H. W. (1990). Gender differences in beliefs and achievement: A cross-cultural study. *Developmental Psychology, 26*(2), 254–263. https://doi.org/10.1037/0012-1649.26.2.254

Lyons, I. M., Beilock, S. L., & Chapouthier, G. (2012). When math hurts: Math anxiety predicts pain network activation in anticipation of doing math. *PloS One, 7*(10), e48076. https://doi.org/10.1371/journal.pone.0048076
Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30*(5), 520–540. https://doi.org/10.2307/749772
Ma, X., & Kishor, N. (1997). Attitude toward self, social factors, and achievement in mathematics: A meta-analytic review. *Educational Psychology Review, 9*(2), 89–120. https://doi.org/10.1023/A:1024785812050
Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: A longitudinal panel analysis. *Journal of Adolescence, 27*(2), 165–179. https://doi.org/10.1016/j.adolescence.2003.11.003
Malanchini, M., Rimfeld, K., Shakeshaft, N. G., Rodic, M., Schofield, K., Selzam, S., Dale, P. S., Petrill, S. A., & Kovas, Y. (2017). The genetic and environmental aetiology of spatial, mathematics and general anxiety. *Scientific Reports, 7*, 42218. https://doi.org/10.1038/srep42218
Markovits, Z., & Forgasz, H. (2017). "Mathematics is like a lion": Elementary students' beliefs about mathematics. *Educational Studies in Mathematics, 96*(1), 49–64. https://www.jstor.org/stable/45184578.
Marsh, H. W. (1986). Global self-esteem: Its relation to specific facets of self-concept and their importance. *Journal of Personality and Social Psychology, 51*(6), 1224–1236. https://doi.org/10.1037/0022-3514.51.6.1224
Marsh, H. W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early adulthood. *Journal of Educational Psychology, 81*(3), 417–430. https://doi.org/10.1037/0022-0663.81.3.417
Marsh, H. W. (1990). The structure of academic self-concept: The Marsh/Shavelson model. *Journal of Educational Psychology, 82*(4), 623–636. https://doi.org/10.1037/0022-0663.82.4.623
Marsh, H. W., & Craven, R. G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science, 1*(2), 133–163. https://doi.org/10.1111/j.1745-6916.2006.00010.x
Marsh, H. W., Craven, R. G., & Debus, R. (1991). Self-concepts of young children 5 to 8 years of age: Measurement and multidimensional structure. *Journal of Educational Psychology, 83*(3), 377–392. https://doi.org/10.1037/0022-0663.83.3.377
Marsh, H. W., Craven, R., & Debus, R. (1998). Structure, stability, and development of young children's self-concepts: A multicohort–multioccasion study. *Child Development, 69*(4), 1030–1053. https://doi.org/10.2307/1132361
Marsh, H. W., Ellis, L. A., & Craven, R. G. (2002). How do preschool children feel about themselves? Unraveling measurement and multidimensional self-concept structure. *Developmental Psychology, 38*(3), 376–393. https://doi.org/10.1037/0012-1649.38.3.376
Marsh, H. W., Trautwein, U., Lüdtke, O., Köller, O., & Baumert, Jürgen (2005). Academic self-concept, interest, grades, and standardized test scores: Reciprocal effects models of causal ordering. *Child Development, 76*(2), 397–416. https://doi.org/10.1111/j.1467-8624.2005.00853.x
Marsh, H. W., & Yeung, A. S. (1998). Longitudinal structural equation models of academic self-concept and achievement: Gender differences in the development of math and English constructs. *American Educational Research Journal, 35*(4), 705–738. https://doi.org/10.2307/1163464
Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A. N. (2017). Programming experience promotes higher STEM motivation among first-grade girls. *Journal of Experimental Child Psychology, 160*, 92–106. https://doi.org/10.1016/j.jecp.2017.03.013
Master, A., & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *International Journal of Gender, Science and Technology, 12*(1), 152–198. http://genderandset.open.ac.uk/index.php/genderandset/article/view/674.
Maloney, E. A., Ansari, D., & Fugelsang, J. A. (2011). Rapid communication: The effect of mathematics anxiety on the processing of numerical magnitude. *Quarterly Journal of Experimental Psychology, 64*(1), 10–16. https://doi.org/10.1080/17470218.2010.533278
Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science, 26*(9), 1480–1488. https://doi.org/10.1177/0956797615592630
Maloney, E. A., Risko, E. F., Ansari, D., & Fugelsang, J. (2010). Mathematics anxiety affects counting but not subitizing during visual enumeration. *Cognition, 114*(2), 293–297. https://doi.org/10.1016/j.cognition.2009.09.013
Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*(1), 60–70. https://doi.org/10.1037/0022-0663.82.1.60
Meltzoff, A. N., & Cvencek, D. (2019). How stereotypes shape children's STEM identity and learning. In P. K. Kuhl, -S.- S. Lim, S. Guerriero, & D. van Damme (Eds.), Developing minds in the digital age: Towards a science of learning for 21st century education (pp. 37–47). OECD. Doi: 10.1787/43e5bb4c-en.
Mesghina, A., & Richland, L. E. (2020). Impacts of expressive writing on children's anxiety and mathematics learning: Developmental and gender variability. *Contemporary Educational Psychology, 63*, 101926. https://doi.org/10.1016/j.cedpsych.2020.101926
Meyer, M., Cimpian, A., & Leslie, S. J. (2015). Women are underrepresented in fields where success is believed to require brilliance. *Frontiers in Psychology, 6*, 235. https://doi.org/10.3389/fpsyg.2015.00235
Miele, D. B., Son, L. K., & Metcalfe, J. (2013). Children's naive theories of intelligence influence their metacognitive judgments. *Child Development, 84*(6), 1879–1886. https://doi.org/10.1111/cdev.2013.84.issue-610.1111/cdev.12101
Miller, D. I., Eagly, A. H., & Linn, M. C. (2015). Women's representation in science predicts national gender science stereotypes: Evidence from 66 nations. *Journal of Educational Psychology, 107*(3), 631–644. https://doi.org/10.1037/edu0000005
Miller, D. I., & Halpern, D. F. (2014). The new science of cognitive sex differences. *Trends in Cognitive Sciences, 18*(1), 37–45. https://doi.org/10.1016/j.tics.2013.10.011
Mix, K. S., Levine, S. C., Cheng, Y.-L., Stockton, J. D., & Bower, C. (2020). Effects of spatial training on mathematics in first and sixth grade children. *Journal of Educational Psychology, 113*(2), 304–314. https://doi.org/10.1037/edu0000494
Mix, K. S., Levine, S. C., Cheng, Y. L., Young, C. J., Hambrick, D. Z., & Konstantopoulos, S. (2017). The latent structure of spatial skills and mathematics: A replication of the two-factor model. *Journal of Cognition and Development, 18*(4), 465–492. https://doi.org/10.1080/15248372.2017.1346658
Mix, K. S., Levine, S. C., Cheng, Y. L., Young, C., Hambrick, D. Z., Ping, R., & Konstantopoulos, S. (2016). Separate but correlated: The latent structure of space and mathematics across development. *Journal of Experimental Psychology: General, 145*(9), 1206–1227. https://doi.org/10.1037/xge0000182
Mizala, A., Martínez, F., & Martínez, S. (2015). Pre-service elementary school teachers' expectations about student performance: How their beliefs are affected by their mathematics anxiety and student's gender. *Teaching and Teacher Education, 50*, 70–78. https://doi.org/10.1016/j.tate.2015.04.006
Möller, J., Pohlmann, B., Köller, O., & Marsh, H. W. (2009). A meta-analytic path analysis of the internal/external frame of reference model of academic achievement and academic self-concept. *Review of Educational Research, 79*(3), 1129–1167. https://doi.org/10.3102/0034654309337522
Möller, J., Retelsdorf, J., Köller, O., & Marsh, H. W. (2011). The reciprocal internal/external frame of reference model: An integration of models of relations between academic achievement and self-concept. *American Educational Research Journal, 48*(6), 1315–1346. https://doi.org/10.3102/0002831211419649
Moorman, E. A., & Pomerantz, E. M. (2010). Ability mindsets influence the quality of mothers' involvement in children's learning: An experimental investigation. *Developmental Psychology, 46*(5), 1354–1362. https://doi.org/10.1037/a0020376
Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of Personality and Social Psychology, 75*(1), 33–52. https://doi.org/10.1037/0022-3514.75.1.33
Muenks, K., & Miele, D. B. (2017). Students' thinking about effort and ability: The role of developmental, contextual, and individual differences factors. *Review of Educational Research, 87*(4), 707–735. https://doi.org/10.3102/0034654316689328
Muenks, K., Miele, D. B., Ramani, G. B., Stapleton, L. M., & Rowe, M. L. (2015). Parental beliefs about the fixedness of ability. *Journal of Applied Developmental Psychology, 41*, 78–89. https://doi.org/10.1016/j.appdev.2015.08.002
Muradoglu, M., & Cimpian, A. (2020). Children's intuitive theories of academic performance. *Child Development, 91*(4), e902–e918. https://doi.org/10.1111/cdev.13325
Murnane, R. J., Willett, J. B., & Levy, F. (1995). The growing importance of cognitive skills in wage determination. *The Review of Economics and Statistics, 77*(2), 251–266. https://doi.org/10.3386/w5076

Musu-Gillette, L. E., Wigfield, A., Harring, J. R., & Eccles, J. S. (2015). Trajectories of change in students' self-concepts of ability and values in math and college major choice. *Educational Research and Evaluation, 21*(4), 343–370. https://doi.org/10.1080/13803611.2015.1057161
Muzzatti, B., & Agnoli, F. (2007). Gender and mathematics: Attitudes and stereotype threat susceptibility in Italian children. *Developmental Psychology, 43*(3), 747–759. https://doi.org/10.1037/0012-1649.43.3.747
Nagy, G., Watt, H. M. G., Eccles, J. S., Trautwein, U., Lüdtke, O., & Baumert, J. (2010). The development of students' mathematics self-concept in relation to gender: Different countries, different trajectories? *Journal of Research on Adolescence, 20*(2), 482–506. https://doi.org/10.1111/j.1532-7795.2010.00644.x
Namkung, J. M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: A meta-analysis. *Review of Educational Research, 89*(3), 459–496. https://doi.org/10.3102/0034654319843494
National Mathematics Advisory Panel. (2008). Foundations for success: The final report of the National Mathematics Advisory Panel. US Department of Education.
Neuville, E., & Croizet, J. C. (2007). Can salience of gender identity impair math performance among 7–8 years old girls? The moderating role of task difficulty. *European Journal of Psychology of Education, 22*(3), 307–316. https://www.jstor.org/stable/23421747.
Nhundu, T. J. (2007). Mitigating gender-typed occupational preferences of Zimbabwean primary school children: The use of biographical sketches and portrayals of female role models. *Sex Roles, 56*(9–10), 639–649. https://doi.org/10.1007/s11199-007-9204-6
Nicholls, J. G. (1978). The development of the concepts of effort and ability, perception of academic attainment, and the understanding that difficult tasks require more ability. *Child Development, 49*(3), 800–814. https://doi.org/10.2307/1128250
Nicholls, J. G., & Miller, A. T. (1984). Reasoning about the ability of self and others: A developmental study. *Child Development, 55*(6), 1990–1999. https://doi.org/10.2307/1129774
Niepel, C., Stadler, M., & Greiff, S. (2019). Seeing is believing: Gender diversity in STEM is related to mathematics self-concept. *Journal of Educational Psychology, 111*(6), 1119–1130. https://doi.org/10.1037/edu0000340
Nosek, B. A., & Banaji, M. R. (2001). The go/no go association task. *Social Cognition, 19*(6), 625–666. https://doi.org/10.1521/soco.2001.19.issue-610.1521/soco.19.6.625.20886
Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Math = male, me = female, therefore math = me. *Journal of Personality and Social Psychology, 83*, 44–59. https://doi.org/10.1037/0022-3514.83.1.44
Nosek, B., Greenwald, A. G., & Banaji, M. R. (2007). The implicit association test at age 7: A methodological and conceptual review. In J. A. Bargh (Ed.), *Automatic processes in social thinking and behavior* (pp. 265–292). Psychology Press.
Nosek, B. A., & Smyth, F. L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. *American Educational Research Journal, 48*(5), 1125–1156. https://doi.org/10.3102/0002831211410683
Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., … Greenwald, A. G. (2009). National differences in gender–science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences, 106*(26), 10593–10597. https://doi.org/10.1073/pnas.0809921106
O'Keefe, P. A., Dweck, C. S., & Walton, G. M. (2018). Implicit theories of interest: Finding your passion or developing it? *Psychological Science, 29*(10), 1653–1664. https://doi.org/10.1177/0956797618780643
O'Keefe, P. A., & Harackiewicz, J. M. (Eds.). (2017). *The Science of Interest*. Cham: Springer International Publishing.
Organisation for Economic Co-operation and Development (2006). Evolution of student interest in science and technology studies: Policy report. OECD Global Science Forum. http://www.oecd.org/sti/inno/36645825.pdf.
Organisation for Economic Co-operation and Development. (2012). Closing the Gender Gap: Act Now. OECD Publishing. Doi: 10.1787/9789264179370-en.
Organisation for Economic Co-operation and Development. (2017). The Pursuit of Gender Equality-An Uphill Battle. OECD Publishing. Doi: 10.1787/9789264281318-en.
Organisation for Economic Cooperation and Development. (2015). What Lies Behind Gender Inequality in Education? OECD Publishing. Doi: 10.1787/5js4xffhhc30-en.
Olsson, M., & Martiny, S. E. (2018). Does exposure to counterstereotypical role models influence girls' and women's gender stereotypes and career choices? A review of social psychological research. *Frontiers in Psychology, 9*, 2264. https://doi.org/10.3389/fpsyg.2018.02264
O'Mara, A. J., Marsh, H. W., Craven, R. G., & Debus, R. L. (2006). Do self-concept interventions make a difference? A synergistic blend of construct validation and meta-analysis. *Educational Psychologist, 41*(3), 181–206. https://doi.org/10.1207/s15326985ep4103_4
Pantoja, N., Schaeffer, M. W., Rozek, C. S., Beilock, S. L., & Levine, S. C. (2020). Children's Math Anxiety Predicts Their Math Achievement Over and Above a Key Foundational Math Skill. *Journal of Cognition and Development, 21*(5), 709–728. https://doi.org/10.1080/15248372.2020.1832098
Park, D., Gunderson, E. A., Tsukayama, E., Levine, S. C., & Beilock, S. L. (2016). Young children's motivational frameworks and math achievement: Relation to teacher-reported instructional practices, but not teacher theory of intelligence. *Journal of Educational Psychology, 108*(3), 300–313. https://doi.org/10.1037/edu0000064
Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of Experimental Psychology: Applied, 20*(2), 103–111. https://doi.org/10.1037/xap0000013
Parsons, J. E., Adler, T. F., & Kaczala, C. M. (1982). Socialization of achievement attitudes and beliefs: Parental influences. *Child Development, 53*(2), 310–321. https://doi.org/10.2307/1128973
Passolunghi, M. C., Terreira, R. F., & Tomasetto, C. (2014). Math-gender stereotypes and math-related beliefs in childhood and early adolescence. *Learning and Individual Differences, 34*, 70–76. https://doi.org/10.1016/j.lindif.2014.05.005
Pekrun, R., Lichtenfeld, S., Marsh, H. W., Murayama, K., & Goetz, T. (2017). Achievement emotions and academic performance: Longitudinal models of reciprocal effects. *Child Development, 88*(5), 1653–1670. https://doi.org/10.1111/cdev.12704
Pinxten, M., Marsh, H. W., De Fraine, B., Van Den Noortgate, W., & Van Damme, J. (2014). Enjoying mathematics or feeling competent in mathematics? Reciprocal effects on mathematics achievement and perceived math effort expenditure. *British Journal of Educational Psychology, 84*(1), 152–174. https://doi.org/10.1111/bjep.12028
Pomerantz, E. M., Altermatt, E. R., & Saxon, J. L. (2002). Making the grade but feeling distressed: Gender differences in academic performance and internal distress. *Journal of Educational Psychology, 94*(2), 396–404. https://doi.org/10.1037/0022-0663.94.2.396
Pomerantz, E. M., & Kempner, S. G. (2013). Mothers' daily person and process praise: Implications for children's theory of intelligence and motivation. *Developmental Psychology, 49*(11), 2040–2046. https://doi.org/10.1037/a0031840
Pomerantz, E. M., & Ruble, D. N. (1997). Distinguishing multiple dimensions of conceptions of ability: Implications for self-evaluation. *Child Development, 68*(6), 1165–1180. https://doi.org/10.2307/1132299
Pomerantz, E. M., & Saxon, J. L. (2001). Conceptions of ability as stable and self-evaluative processes: A longitudinal examination. *Child Development, 72*(1), 152–173. https://doi.org/10.1111/cdev.2001.72.issue-110.1111/1467-8624.00271
Pruden, S. M., & Levine, S. C. (2017). Parents' spatial language mediates a sex difference in preschoolers' spatial-language use. *Psychological Science, 28*(11), 1583–1596. https://doi.org/10.1177/0956797617711968
Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education, 5*(1), 1–14. https://doi.org/10.1186/s40594-018-0115-6
Ramirez, G., & Beilock, S. L. (2011). Writing about testing worries boosts exam performance in the classroom. *Science, 331*(6014), 211–213. https://doi.org/10.1126/science.1199427
Ramirez, G., Chang, H., Maloney, E. A., Levine, S. C., & Beilock, S. L. (2016). On the relationship between math anxiety and math achievement in early elementary school: The role of problem solving strategies. *Journal of Experimental Child Psychology, 141*, 83–100. https://doi.org/10.1016/j.jecp.2015.07.014
Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. *Quarterly Journal of Experimental Psychology, 65*(3), 474–487. https://doi.org/10.1080/17470218.2011.616214

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development, 14*(2), 187–202. https://doi.org/10.1080/15248372.2012.664593
Ramirez, G., Hooper, S. Y., Kersting, N. B., Ferguson, R., & Yeager, D. (2018). Teacher math anxiety relates to adolescent students' math achievement. *AERA Open, 4*(1), 1–13. https://doi.org/10.1177/2332858418756052
Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist, 53*(3), 145–164. https://doi.org/10.1080/00461520.2018.1447384
Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok - not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology, 48*(3), 731–737. https://doi.org/10.1016/j.jesp.2011.12.012
Raudenbush, S. W., Hernandez, M., Goldin-Meadow, S., Carrazza, C., Foley, A., Leslie, D., Sorkin, J. E., & Levine, S. C. (2020). Longitudinally adaptive assessment and instruction increase numerical skills of preschool children. *Proceedings of the National Academy of Sciences, 117*(45), 27945–27953. https://doi.org/10.1073/pnas.2002883117
Régner, I., Steele, J. R., Ambady, N., Thinus-Blanc, C., & Huguet, P. (2014). Our future scientists: A review of stereotype threat in girls from early elementary school to middle school. *Revue Internationale de Psychologie Sociale, 27*(3), 13–51.
Reyna, V. F., & Brainerd, C. J. (2007). The importance of mathematics in health and human judgment: Numeracy, risk communication, and medical decision making. *Learning and Individual Differences, 17*(2), 147–159. https://doi.org/10.1016/j.lindif.2007.03.010
Rholes, W. S., & Ruble, D. N. (1984). Children's understanding of dispositional characteristics of others. *Child Development, 55*(2), 550. https://doi.org/10.2307/1129966
Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology, 19*(6), 551–554. https://doi.org/10.1037/h0033456
Richland, L. E., Naslund-Hadley, E., Alonzo, H., Lyons, E., & Vollman, E. (2020). Teacher and Students' Mathematics Anxiety and Achievement in a Low-Income National Context. *Mind, Brain, and Education, 14*(4), 400–414. https://doi.org/10.1111/mbe.12253
Rietveld, M. J. H., Hudziak, J. J., Bartels, M., Beijsterveldt, C. E. M., & Boomsma, D. I. (2004). Heritability of attention problems in children: Longitudinal results from a study of twins, age 3 to 12. *Journal of Child Psychology and Psychiatry, 45*(3), 577–588. https://doi.org/10.1111/jcpp.2004.45.issue-310.1111/j.1469-7610.2004.00247.x
Robinson-Cimpian, J. P., Lubienski, S. T., Ganley, C. M., & Copur-Gencturk, Y. (2014). Teachers' perceptions of students' mathematics proficiency may exacerbate early gender gaps in achievement. *Developmental Psychology, 50*(4), 1262–1281. https://doi.org/10.1037/a0035073
Romero, C., Master, A., Paunesku, D., Dweck, C. S., & Gross, J. J. (2014). Academic and emotional functioning in middle school: The role of implicit theories. *Emotion, 14*(2), 227–234. https://doi.org/10.1037/a0035490
Rose, H., & Betts, J. R. (2004). The effect of high school courses on earnings. *Review of Economics and Statistics, 86*(2), 497–513. https://doi.org/10.1162/003465304323031076
Rosenholtz, S. J., & Rosenholtz, S. H. (1981). Classroom organization and the perception of ability. *Sociology of Education*, 132–140. https://www.jstor.org/stable/1001616.
Rudman, L. A. (2004). Sources of implicit attitudes. *Current Directions in Psychological Science, 13*(2), 79–82. https://doi.org/10.1111/j.0963-7214.2004.00279.x
Ryckman, D. B., & Peckham, P. (1987). Gender differences in attributions for success and failure situations across/subject areas. *The Journal of Educational Research, 81*(2), 120–125. https://doi.org/10.1080/00220671.1987.10885808
Satake, E., & Amato, P. P. (1995). Mathematics anxiety and achievement among Japanese elementary school students. *Educational and Psychological Measurement, 55*(6), 1000–1007. https://doi.org/10.1177/0013164495055006009
Schaeffer, M. W., Rozek, C. S., Berkowitz, T., Levine, S. C., & Beilock, S. L. (2018). Disassociating the relation between parents' math anxiety and children's math achievement: Long-term effects of a math app intervention. *Journal of Experimental Psychology: General, 147*(12), 1782–1790. https://doi.org/10.1037/xge0000490
Schaeffer, M. W., Rozek, C. S., Maloney, E. A., Berkowitz, T., Levine, S. C., & Beilock, S. L. (2020). Elementary School Teachers' Math Anxiety and Students' Math Learning: A Large-Scale Replication. *Developmental Science*. https://doi.org/10.1037/xge0000490
Schleepen, T. M., & Van Mier, H. I. (2016). Math anxiety differentially affects boys' and girls' arithmetic, reading and fluid intelligence skills in fifth graders. *Psychology, 7*(14), 1911–1920. https://doi.org/10.4236/psych.2016.714174
Schmader, T., & Johns, M. (2003). Converging evidence that stereotype threat reduces working memory capacity. *Journal of Personality and Social Psychology, 85*(3), 440. https://doi.org/10.1037/0022-3514.85.3.440
Sewasew, D., Schroeders, U., Schiefer, I. M., Weirich, S., & Artelt, C. (2018). Development of sex differences in math achievement, self-concept, and interest from grade 5 to 7. *Contemporary Educational Psychology, 54*, 55–65. https://doi.org/10.1016/j.cedpsych.2018.05.003
Shih, M., Pittinsky, T. L., & Ambady, N. (1999). Stereotype susceptibility: Identity salience and shifts in quantitative performance. *Psychological Science, 10*(1), 80–83. https://doi.org/10.1111/1467-9280.00111
Sierksma, J., & Shutts, K. (2020). When Helping Hurts: Children Think Groups That Receive Help Are Less Smart. *Child Development, 91*(3), 715–723. https://doi.org/10.1111/cdev.v91.310.1111/cdev.13351
Silinskas, G., & Kikas, E. (2019). Parental involvement in math homework: Links to children's performance and motivation. *Scandinavian Journal of Educational Research, 63*(1), 17–37. https://doi.org/10.1080/00313831.2017.1324901
Simmons, R. G., Black, A., & Zhou, Y. (1991). African-American versus White children and the transition into junior high school. *American Journal of Education, 99*(4), 481–520. https://doi.org/10.1086/443995
Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2005). Parents' socializing behavior and children's participation in math, science, and computer out-of-school activities. *Applied Developmental Science, 9*(1), 14–30. https://doi.org/10.1207/s1532480xads0901_3
Simpkins, S. D., Fredricks, J. A., & Eccles, J. S. (2012). Charting the Eccles' expectancy-value model from mothers' beliefs in childhood to youths' activities in adolescence. *Developmental Psychology, 48*(4), 1019–1302. https://doi.org/10.1037/a0027468
Sisk, V. F., Burgoyne, A. P., Sun, J., Butler, J. L., & Macnamara, B. N. (2018). To what extent and under which circumstances are growth mind-sets important to academic achievement? *Two meta-analyses. Psychological Science, 29*(4), 549–571. https://doi.org/10.1177/0956797617739704
Skaalvik, S., & Skaalvik, E. M. (2004). Gender differences in math and verbal self-concept, performance expectations, and motivation. *Sex Roles, 50*(3–4), 241–252. https://doi.org/10.1023/B:SERS.0000015555.40976.e6
Sokolowski, H. M., Hawes, Z., & Lyons, I. M. (2019). What explains sex differences in math anxiety? A closer look at the role of spatial processing. *Cognition, 182*, 193–212. https://doi.org/10.1016/j.cognition.2018.10.005
Soni, A., & Kumari, S. (2017). The role of parental math anxiety and math attitude in their children's math achievement. *International Journal of Science and Mathematics Education, 15*(2), 331–347. https://doi.org/10.5923/j.ijas.20150504.01
Sorvo, R., Koponen, T., Viholainen, H., Aro, T., Räikkönen, E., Peura, P., Dowker, A., & Aro, M. (2017). Math anxiety and its relationship with basic arithmetic skills among primary school children. *British Journal of Educational Psychology, 87*(3), 309–327. https://doi.org/10.1111/bjep.2017.87.issue-310.1111/bjep.12151
Sorvo, R., Koponen, T., Viholainen, H., Aro, T., Räikkönen, E., Peura, P., Tolvanen, A., & Aro, M. (2019). Development of math anxiety and its longitudinal relationships with arithmetic achievement among primary school children. *Learning and Individual Differences, 69*, 173–181. https://doi.org/10.1016/j.lindif.2018.12.005
Spelke, E. S. (2005). Sex differences in intrinsic aptitude for mathematics and science?: A critical review. *American Psychologist, 60*(9), 950–958. https://doi.org/10.1037/0003-066X.60.9.950
Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology, 35*(1), 4–28. https://doi.org/10.1006/jesp.1998.1373
Stankov, L. (2010). Unforgiving Confucian culture: A breeding ground for high academic achievement, test anxiety and self-doubt? *Learning and Individual Differences, 20*(6), 555–563. https://doi.org/10.1016/j.lindif.2010.05.003

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52*(6), 613–629. https://doi.org/10.1037/0003-066X.52.6.613

Steele, J. (2003). Children's Gender Stereotypes About Math: The Role of Stereotype Stratification 1. *Journal of Applied Social Psychology, 33*(12), 2587–2606. https://doi.org/10.1111/jasp.2003.33.issue-1210.1111/j.1559-1816.2003.tb02782.x

Steele, J. R., Reisz, L., Williams, A., & Kawakami, K. (2007). Women in mathematics: Examining the hidden barriers that gender stereotypes can impose. In R. J. Burke, & M. C. Mattis (Eds.), *Women and minorities in science, technology, engineering and mathematics: Upping the numbers* (pp. 159–182). Edward Elgar Publishing.

Steffens, M. C., & Jelenec, P. (2011). Separating implicit gender stereotypes regarding math and language: Implicit ability stereotypes are self-serving for boys and men, but not for girls and women. *Sex Roles, 64*(5–6), 324–335. https://doi.org/10.1007/s11199-010-9924-x

Steffens, M. C., Jelenec, P., & Noack, P. (2010). On the leaky math pipeline: Comparing implicit math-gender stereotypes and math withdrawal in female and male children and adolescents. *Journal of Educational Psychology, 102*(4), 947–963. https://doi.org/10.1037/a0019920

Stipek, D. J., & Daniels, D. H. (1988). Declining perceptions of competence: A consequence of changes in the child or in the educational environment? *Journal of Educational Psychology, 80*(3), 352–356. https://doi.org/10.1037/0022-0663.80.3.352

Stipek, D. J., & Daniels, D. H. (1990). Children's use of dispositional attributions in predicting the performance and behavior of classmates. *Journal of Applied Developmental Psychology, 11*(1), 13–28. https://doi.org/10.1016/0193-3973(90)90029-J

Stipek, D. J., & Gralinski, J. H. (1991). Gender differences in children's achievement-related beliefs and emotional responses to success and failure in mathematics. *Journal of Educational Psychology, 83*(3), 361–371. https://doi.org/10.1037/0022-0663.83.3.361

Stipek, D., & Gralinski, J. H. (1996). Children's beliefs about intelligence and school performance. *Journal of Educational Psychology, 88*(3), 397–407. https://doi.org/10.1037/0022-0663.88.3.397

Stodolsky, S., Salk, S., & Glaessner, B. (1991). Student view about learning math and social studies. *American Educational Research Journal, 28*(1), 89–116. https://doi.org/10.3102/00028312028001089

Stoeger, H., Schirner, S., Laemmle, L., Obergriesser, S., Heilemann, M., & Ziegler, A. (2016). A contextual perspective on talented female participants and their development in extracurricular STEM programs. *Annals of the New York Academy of Sciences, 1377*(2016), 53–63. https://doi.org/10.1111/nyas.13116

Stoet, G., Bailey, D. H., Moore, A. M., & Geary, D. C. (2016). Countries with higher levels of gender equality show larger national sex differences in mathematics anxiety and relatively lower parental mathematics valuation for girls. PloS One, 11(4). Doi: 10.1371/journal.pone.0153857.

Stoet, G., & Geary, D. C. (2012). Can stereotype threat explain the gender gap in mathematics performance and achievement? *Review of General psychology, 16*(1), 93–102.

Stoet, G., & Geary, D. C. (2013). Sex differences in mathematics and reading achievement are inversely related: Within-and across-nation assessment of 10 years of PISA data. *PloS One, 8*(3). https://doi.org/10.1371/journal.pone.0153857

Stoet, G., & Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science, 29*(4), 581–593. https://doi.org/10.1177/0956797617741719

Stout, J. G., Dasgupta, N., Hunsinger, M., & McManus, M. A. (2011). STEMing the tide: Using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology, 100*(2), 255–270. https://doi.org/10.1037/a0021385

Supekar, K., Iuculano, T., Chen, L., & Menon, V. (2015). Remediation of childhood math anxiety and associated neural circuits through cognitive tutoring. *Journal of Neuroscience, 35*(36), 12574–12583. https://doi.org/10.1523/JNEUROSCI.0786-15.2015

Swars, S. L., Daane, C. J., & Giesen, J. (2006). Mathematics anxiety and mathematics teacher efficacy: What is the relationship in elementary preservice teachers? *School Science and Mathematics, 106*(7), 306–315. https://doi.org/10.1111/j.1949-8594.2006.tb17921.x

Tiedemann, J. (2000a). Gender-related beliefs of teachers in elementary school mathematics. *Educational Studies in Mathematics, 41*(2), 191–207. https://doi.org/10.1023/A:1003953801526

Tiedemann, J. (2000b). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. *Journal of Educational Psychology, 92*(1), 144. https://doi.org/10.1023/A:1020518104346

Tiedemann, J. (2002). Teachers' gender stereotypes as determinants of teacher perceptions in elementary school mathematics. *Educational Studies in Mathematics, 50*(1), 49–62.

Todor, I. (2014). Investigating "the old stereotype" about boys/girls and mathematics: Gender differences in implicit theory of intelligence and mathematics self-efficacy beliefs. *Procedia-Social and Behavioral Sciences, 159*, 319–323. https://doi.org/10.1016/j.sbspro.2014.12.380

Tomasetto, C. (2019). Gender stereotypes, anxiety, and math outcomes in adults and children. In I. C. Mammarella, S. Caviola, & A. Dowker (Eds.), *Mathematics anxiety: What is known, and what is still missing* (pp. 178–189). Routledge.

Tomasetto, C., Alparone, F. R., & Cadinu, M. (2011). Girls' math performance under stereotype threat: The moderating role of mothers' gender stereotypes. *Developmental Psychology, 47*(4), 943–949. https://doi.org/10.1037/a0024047

Tozzo, S. G., & Golub, S. (1990). Playing nurse and playing cop: Do they change children's perceptions of sex-role stereotypes? *Journal of Research in Childhood Education, 4*(2), 123–129. https://doi.org/10.1080/02568549009594793

Trepanier-Street, M. L., & Romatowski, J. A. (1999). The influence of children's literature on gender role perceptions: A reexamination. *Early Childhood Education Journal, 26*(3), 155–159. https://doi.org/10.1023/A:1022977317864

Tsui, M., Xu, X. Y., & Venator, E. (2011). Gender, stereotype threat and mathematics test scores. *Journal of Social Sciences, 7*(4), 538–549. https://doi.org/10.3844/jssp.2011.538.549

Upadyaya, K., Eccles, J. S., Schoon, I., & Eccles, J. S. (2014). In *Gender Differences in Aspirations and Attainment: A Life Course Perspective* (pp. 79–100). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139128933.006.

Upadyaya, K., & Eccles, J. (2015). Do teachers' perceptions of children's math and reading related ability and effort predict children's self-concept of ability in math and reading? *Educational Psychology, 35*(1), 110–127. https://doi.org/10.1080/01443410.2014.915927

Valeski, T. N., & Stipek, D. J. (2001). Young children's feelings about school. *Child Development, 72*(4), 1198–1213. https://doi.org/10.1111/cdev.2001.72.issue-410.1111/1467-8624.00342

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education, 41*(2), 150–164. https://doi.org/10.1080/09500693.2018.1540897

Van der Beek, J. P. J., Van der Ven, S. H. G., Kroesbergen, E. H., & Leseman, P. P. M. (2017). Self-concept mediates the relation between achievement and emotions in mathematics. *British Journal of Educational Psychology, 87*(3), 478–495. https://doi.org/10.1111/bjep.2017.87.issue-310.1111/bjep.12160

Van Mier, H. I., Schleepen, T. M., & Van den Berg, F. C. (2019). Gender differences regarding the impact of math anxiety on arithmetic performance in second and fourth graders. *Frontiers in Psychology, 9*, 2690. https://doi.org/10.3389/fpsyg.2018.02690

Verniers, C., & Martinot, D. (2015). Perception of students' intelligence malleability and potential for future success: Unfavourable beliefs towards girls. *British Journal of Educational Psychology, 85*(3), 289–299. https://doi.org/10.1111/bjep.2015.85.issue-310.1111/bjep.12073

Vukovic, R. K., Kieffer, M. J., Bailey, S. P., & Harari, R. R. (2013). Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance. *Contemporary Educational Psychology, 38*(1), 1–10. https://doi.org/10.1016/j.cedpsych.2012.09.001

Wai, J., Cacchio, M., Putallaz, M., & Makel, M. C. (2010). Sex differences in the right tail of cognitive abilities: A 30 year examination. *Intelligence, 38*(4), 412–423. https://doi.org/10.1016/j.intell.2010.04.006

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology, 101*(4), 817–835. https://doi.org/10.1037/a0016127

Walton, G. M., & Cohen, G. L. (2003). Stereotype lift. *Journal of Experimental Social Psychology, 39*(5), 456–467. https://doi.org/10.1016/S0022-1031(03)00019-2

Wang, Z., Hart, S. A., Kovas, Y., Lukowski, S., Soden, B., Thompson, L. A., … Petrill, S. A. (2014). Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *Journal of Child Psychology and Psychiatry, 55*(9), 1056–1064. https://doi.org/10.1111/jcpp.12224

Wang, Z., Rimfeld, K., Shakeshaft, N., Schofield, K., & Malanchini, M. (2020). The longitudinal role of mathematics anxiety in mathematics development: Issues of gender differences and domain-specificity. *Journal of Adolescence, 80*, 220–232. https://doi.org/10.1016/j.adolescence.2020.03.003

Weidinger, A. F., Steinmayr, R., & Spinath, B. (2018). Changes in the relation between competence beliefs and achievement in math across elementary school years. *Child Development, 89*(2), e138–e156. https://doi.org/10.1111/cdev.12806

Wigfield, A., Byrnes, J. P., & Eccles, J. S. (2006). Development During Early and Middle Adolescence. In P. A. Alexander, & P. H. Winne (Eds.), *Handbook of Educational Psychology* (pp. 87–113). Lawrence Erlbaum Associates Publishers.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015

Wigfield, A., & Eccles, J. S. (2020). 35 years of research on students' subjective task values and motivation: A look back and a look forward. In A. Elliot (Ed.), Advances in Motivation Science (Vol. 7, pp. 161-198). Elsevier. Doi: 10.1016/bs.adms.2019.05.002.

Wigfield, A., Eccles, J. S., Fredricks, J. A., Simpkins, S., Roeser, R. W., & Schiefele, U. (2015). Development of achievement motivation and engagement. In R. Lerner (Series Ed.) & M. Lamb & C. Garcia Coll (Vol. Eds.), Handbook of Child Psychology (7th ed., Vol. 3). Wiley. Doi: 10.1002/9781118963418.childpsy316.

Wigfield, A., Eccles, J. S., Mac Iver, D., Reuman, D. A., & Midgley, C. (1991). Transitions during early adolescence: Changes in children's domain-specific self-perceptions and general self-esteem across the transition to junior high school. *Developmental Psychology, 27*(4), 552–565. https://doi.org/10.1037/0022-0663.89.3.451

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology, 89*(3), 451–469. https://doi.org/10.1037/0022-0663.89.3.451

Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology, 80*(2), 210–216. https://doi.org/10.1037/0022-0663.80.2.210

Wolff, J. (2021). How classmates' gender stereotypes affects students' math self-concepts: A multilevel analysis. *Frontiers in Psychology, 92*. https://doi.org/10.3389/fpsyg.2021.599199

Wu, S., Amin, H., Barth, M., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology, 3*, 162. https://doi.org/10.3389/fpsyg.2012.00162

Wu, S. S., Willcutt, E. G., Escovar, E., & Menon, V. (2014). Mathematics achievement and anxiety and their relation to internalizing and externalizing behaviors. *Journal of Learning Disabilities, 47*(6), 503–514. https://doi.org/10.1177/0022219412473154

Yamamoto, Y., & Holloway, S. D. (2010). Parental expectations and children's academic performance in sociocultural context. *Educational Psychology Review, 22*(3), 189–214. https://doi.org/10.1007/s10648-010-9121-z

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302–314. https://doi.org/10.1080/00461520.2012.722805

Yeager, D. S., Hanselman, P., Walton, G. M., Murray, J. S., Crosnoe, R., Muller, C., … Dweck, C. S. (2019). A national experiment reveals where a growth mindset improves achievement. *Nature, 573*(7774), 364–369. https://doi.org/10.1038/s41586-019-1466-y

Yeager, D. S., Lee, H. Y., & Jamieson, J. P. (2016). How to improve adolescent stress responses: Insights from integrating implicit theories of personality and biopsychosocial models. *Psychological Science, 27*(8), 1078–1091.

Yeager, D. S., Paunesku, D., Walton, G. M., & Dweck, C. S. (2013). How can we instill productive mindsets at scale: A review of the evidence and an initial R&D Agenda. *White Paper prepared for the White House meeting on Excellence in Education: The Importance of Academic Mindsets*.

Yeager, D. S., Purdie-Vaughns, V., Garcia, J., Apfel, N., Brzustoski, P., Master, A., Hessert, A., Williams, W. T., Matthew, E., & Cohen, G. L. (2014). Breaking the cycle of mistrust: Wise interventions to provide critical feedback across the racial divide. *Journal of Experimental Psychology: General, 143*(2), 804–824. https://doi.org/10.1037/a0033906

Yee, D. K., & Eccles, J. S. (1988). Parent perceptions and attributions for children's math achievement. *Sex Roles, 19*(5–6), 317–333. https://doi.org/10.1007/BF00289840

Young, C. B., Wu, S. S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychological Science, 23*(5), 492–501. https://doi.org/10.1177/0956797611429134

Yüksel-Şahin, F. (2008). Mathematics anxiety among 4th and 5th grade Turkish elementary school students. *International Electronic Journal of Mathematics Education, 3* (3), 179–192.

Zentall, S. R., & Morris, B. J. (2010). "Good job, you're so smart": The effects of inconsistency of praise type on young children's motivation. *Journal of Experimental Child Psychology, 107*(2), 155–163. https://doi.org/10.1016/j.jecp.2010.04.015

Zhang, J., Zhao, N., & Kong, Q. P. (2019). The relationship between math anxiety and math performance: A meta-analytic investigation. *Frontiers in Psychology, 10*, 1613. https://doi.org/10.3389/fpsyg.2019.01613