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Math achievement, stereotypes, and math self-concepts among elementary-school students in Singapore

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ABSTRACT

Singaporean elementary-school students ($N = 299$) completed Child Implicit Association Tests (Child IAT) as well as explicit measures of gender identity, math–gender stereotypes, and math self-concepts. Students also completed a standardized math achievement test. Three new findings emerged. First, implicit, but not explicit, math self-concepts (*math = me*) were positively related to math achievement on a standardized test. Second, as expected, stronger math–gender stereotypes (*math = boys*) significantly correlated with stronger math self-concepts for boys and weaker math self-concepts for girls, on both implicit and explicit measures. Third, implicit math–gender stereotypes were significantly related to math achievement. These findings show that non-academic factors such as implicit math self-concepts and stereotypes are linked to students' actual math achievement. The findings suggest that measuring individual differences in non-academic factors may be a useful tool for educators in assessing students' academic outcomes.

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In many Western and the Eastern cultures, there is a prevalent stereotype among adults linking mathematics with males (Guiso, Monte, Sapienza, & Zingales, 2008; Nosek et al., 2009). This gender stereotype that "math is for males" may be one of the complex factors contributing to the underrepresentation of girls in science technology, engineering, and mathematics (STEM) and influence children's educational interests and choices (e.g., Ceci, Williams, & Barnett, 2009; Cheryan, Master, & Meltzoff, 2015).

One conjecture is that this societal *stereotype* about gender influences boys and girls differential *identification* with math at early ages (Cvencek, Meltzoff, & Greenwald, 2011). Gender stereotypes may potentially mediate learning and performance in specific academic subjects by influencing students' level of anxiety, interest, and effort they put into learning that domain (Beilock, Gunderson, Ramirez, & Levine, 2010; Steffens, Jelenec, & Noack, 2010). This, in turn, may influence how well students perform in the subject, and their interest in pursuing a career in the STEM disciplines (Denissen, Zarrett, & Eccles, 2007; Liben, Bigler, & Krogh, 2001).

However, when one looks beyond stereotypes to actual math *achievement*, boys do not consistently outperform girls. In the U.S., there is older research reporting that high-school girls score lower than boys on standardized math assessments (Dwyer & Johnson, 1997; Pomerantz, Altermatt, & Saxon, 2002); but newer findings indicate that gap is narrowing or non-existent, at least up to the final years of high school (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Hyde & Mertz, 2009). On the other hand, if one looks at achievement on international standardized math achievement tests, a gender gap favoring boys still exists among U.S. elementary-school students (Provasnik et al., 2012). In Asian countries (e.g., Japan, Singapore, and China), there is no gender gap in mathematical achievement at any age (Organisation for Economic Co-operation and Development [OECD], 2011).

Singapore is a compelling example. The mathematical achievement of students from Singapore—both male and female—is outstanding. Singapore consistently scores as one of the top-achieving countries on the international assessments of standardized math achievement, such as the Trends in International Mathematics and Science Study (TIMSS) or the Program of International Student Assessment (PISA; OECD, 2011). The country's math curriculum is celebrated for its effectiveness and emulated world-wide (Bybee & Kennedy, 2005). On the most recent TIMSS assessment, the male–female difference in average math scores of

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Singaporean boys and girls in Grade 4 was not measurably different (Provasnik et al., 2012). Contrary to what one might expect given these data, however, Cvencek, Meltzoff, and Kapur (2014) found that: (a) Singaporean elementary-school students hold the math–gender stereotype, and (b) Singaporean boys identify more strongly with math than do girls.

Studying the relationship between math achievement, math–gender stereotypes and self-concepts in Singaporean children presents an interesting opportunity for at least two reasons. From a theoretical viewpoint, it is not apparent why—in the absence of any detectable boy superiority in math—Singaporean children would hold the stereotype that "*math = boys*," nor why Singaporean boys would identify with math more strongly than girls. From a more methodological viewpoint, a centralized common curriculum for Singaporean K–12 students enables testing of the relationship between students' beliefs and actual math achievement (on which past research has remained silent), by allowing researchers to use standardized math achievement scores for each grade.

1. Role of non-academic factors in math achievement

When examining students' beliefs about math and their math achievement, it is useful to distinguish three interrelated constructs. One is *gender identity*, that is, how strongly a child identifies with being either *boy* or *girl*. A second is the child's belief about the link between math and gender (i.e., a belief about a social group and "who does math"), which can be called a *math–gender stereotype*. The third is how strongly the child connects *me* and *math* (a belief about the self; whether "I identify with math"), which can be called a *math self-concept*.

The current research is motivated by the concept of cognitive balance or consistency in social psychology and developmental psychology. The general idea is that the child and adult usually tend towards a state of psychological equilibrium and minimize dissonance (Festinger, 1957; Gawronski & Strack, 2012; Greenwald et al., 2002; Heider, 1946)—a process related to what Piaget called psychological "equilibration" in human development and education (Piaget, 1970). These general ideas about cognitive consistency and balance can be operationalized and made more precise, particularly about issues of identity (Greenwald et al., 2002). To be fully "in balance" a child who thinks *me = boy*, and *boy = math*, should experience a psychological pressure (conscious or unconscious) towards *me = math*. Such a pressure toward cognitive balance has been hypothesized to operate in young children and to motivate behavioral change and strivings even during elementary-school years (Cvencek et al., 2011, 2014).

As part of investigating cognitive balance in the current study, we specifically examine the role of gender identity and its relation to gender stereotypes and math self-concepts. Gender identity is an early developing aspect of a child's sense of self (Ruble, Martin, & Berenbaum, 2006; Stipek, Gralinski, & Kopp, 1990). We believe that the strength of gender identity (*me = boy* or *me = girl*) could be one factor that works to strengthen (in case of boys) or weaken (in case of girls) a child's identification with mathematics. If *me = girl*, and *girls ≠ math* (according to cultural stereotypes), then cognitive balance may pressure girls in a direction away from math (*me ≠ math*), by changing interest, motivation, choice, and so forth. Of course, in the real-world there are also many other issues that will come into play, but according to social-developmental theory, cognitive balance may be of interest.

2. Stereotypes, self-concepts, and math achievement

When stereotypes are measured in socially sensitive domains, such as gender stereotypes, both implicit and explicit measurement methods have been used. This distinction is based on the idea that human behavior is not only guided by deliberative, conscious processes, but also by more automatic, non-deliberate, and faster processes, which can be captured by two corresponding types of measures, termed *explicit* versus *implicit* measures (Fazio, 1990; Greenwald & Banaji, 1995; Jacoby, 1991; Strack & Deutsch, 2004).

In explicit measures, participants are often asked to provide verbal self-reports and are aware of what is being assessed. For example, this can correspond to an explicit belief about the group with regard to a particular academic ability (e.g., selecting answers on a questionnaire about how much "I believe that boys like math more than girls do?"). In contrast, implicit measures require no self-report and participants are not necessarily informed about what is being assessed. For example, this can correspond to a more unconscious *math = boy* association (e.g., using the same response key to sort stimuli belonging to categories *math* and *boys* in a computerized categorization task that requires fast responses). Few studies have examined both implicit and explicit math–gender stereotypes in the same students, and fewer still have related this to the students' actual math achievement. Three studies and their limitations will be mentioned.

Ambady, Shih, Kim, and Pittinsky (2001) showed that 5-year-old Asian-American girls performed significantly *worse* on a math test, when their gender identity was activated (by being asked to color a picture of a girl holding a doll) relative to a control group. These girls demonstrated math–gender stereotypes on implicit, but not on explicit measures, suggesting that the implicit math–gender stereotypes may have contributed to the observed math performance decrements.

Galdi, Cadinu, and Tomasetto (2014) activated a negative in-group stereotype for 6-year-old Italian girls by asking them to color a picture of a boy who correctly solves a math problem on a blackboard (while a girl fails to respond). Six-year-old Italian girls already possessed implicit math–gender stereotypes (without explicitly endorsing them) and the activation of such stereotypes lead to performance deficits. However, it would be desirable to evaluate the relationship between math–gender stereotypes and math achievement in the absence of experimentally activated identities and without experimentally activating the stereotypes themselves immediately before the math test. This would show that pervasive cultural stereotypes can impact math achievement without salient activation *within the test situation*.

Steffens et al. (2010) used adolescents to examine the relationship between implicit and explicit math–gender stereotypes and math achievement. In their study of German students (Grades 7 and 9), implicit math–gender stereotypes predicted self-reported math grades above and beyond explicit math–gender stereotypes. Potentially, however, the children's self-reports of their latest class test and grades in math (Steffens et al., 2010) are susceptible to inaccuracies in memory, and the social relationship between teacher and student and other factors are known to influence students' grades (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005).

So far we have discussed the relation between math–gender stereotypes and math achievement. Such stereotypes are a belief about math and a social *group* (*math = boys*), but we can also examine beliefs about math and the *self* (*math = me*)—i.e., children's math self-concepts. It is well established using explicit measures that, during elementary school, girls rate themselves lower than boys in mathematics (Herbert & Stipek, 2005), but not in reading or writing (Pajares, Miller, & Johnson, 1999).

What is known about the interrelationship between math self-concepts and math-related outcomes? The emerging evidence can be summarized as follows: First, gender differences in math self-concepts can be independent from actual math achievement, which is often found to be comparable between male and female

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