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Our future scientists: A review of stereotype threat in girls from early elementary school to middle school

Nos futures scientifiques: une revue des effets de menace du stéréotype chez les filles de l'école primaire au collège

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Abstract

The threat of being negatively stereotyped in mathematics can impair the performance of women on difficult math tests, a phenomenon referred to as *stereotype threat* (ST). This phenomenon may help to explain why there are fewer women than men pursuing and succeeding in scientific careers. Although ST effects have emerged repeatedly in studies with college-aged women, far less research to date has examined when and how ST affects the performance of girls in this domain. In this paper we present evidence that gender stereotypes, particularly implicit stereotypes, begin to form in early elementary school and provide a continuing, yet in many ways

Résumé

La crainte d'être négativement stéréotypées en mathématiques peut nuire à la performance des femmes aux tests de mathématiques difficiles, un phénomène appelé *menace du stéréotype* (MS). Ce phénomène peut aider à expliquer pourquoi il y a moins de femmes que d'hommes qui poursuivent des carrières scientifiques et qui y réussissent. Bien que les effets de MS aient été démontrés dans de nombreuses études chez les femmes adultes, beaucoup moins de recherches à ce jour ont examiné quand et comment la MS affecte la performance des filles dans ce domaine. Dans cet article, nous rapportons des résultats qui montrent que les stéréotypes de

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"hidden" barrier to girls' future advancement in scientific domains. We then review both lab and field studies showing that children as young as 5 years of age are susceptible to the influence of both negative and positive stereotypes. The implications of these findings for tackling the thorny issue of ST and for educational interventions are discussed.

genre, en particulier les stéréotypes implicites, commencent à se former dès l'école primaire et constituent à bien des égards un obstacle, souvent invisible, à l'avancement futur des filles dans les domaines scientifiques. Nous passons en revue les études de laboratoire mais aussi de terrain qui montrent que dès l'âge de 5 ans, les enfants sont sensibles à l'influence des stéréotypes négatifs et positifs. Les implications de ces résultats pour la question épineuse de la lutte contre l'effet de MS et pour les interventions éducatives sont discutées.

Although women continue to be underrepresented in science, technology, engineering, and mathematics (STEM) fields (National Center for Education Statistics, 2005; National Science Foundation, 2013; Tietjen, 2004) and have been shown to underperform on complex mathematical problem-solving and standardized tests involving mental rotation (Hyde, 2014; Lindberg, Hyde, Petersen, & Linn, 2010; Miller & Halpern, 2014), a curious paradox presents itself among children. In contrast to the gender differences that have emerged for adults, most available data suggest that girls perform at least as well, if not better, than boys in mathematics during the elementary school years (Hyde & Linn, 2006). Research to date suggests that the majority of gender differences begin to emerge in adolescence (Hyde, Lindberg, Linn, Ellis, & Williams, 2008), with girls being underrepresented among highest achieving 15-year-olds (see the Program for International Student Assessment, OECD, 2012), and these differences continue into university and beyond (Gallagher & Kaufman, 2005; Spelke, 2005; J. R. Steele, 2003). Why might this be the case?

When examining the potential reasons why young girls might *not* be underperforming relative to boys in elementary school mathematics, it is important to consider why women *are* underrepresented in STEM fields relative to men. Although early explanations focused on the possible impact of "intrinsic aptitudes" (see for example, Benbow & Stanley, 1980), and occasional references to this possibility continue to be made (Summers, 2005), current research provides limited support for this explanation (Hyde et al., 2008; Spelke, 2005). Instead, researchers have pointed to a host of social factors that include, but are not limited to, gendered socialization practices (Jacobs & Eccles, 1992; Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005; see also J. R. Steele & Barling, 1996; Tenebaum & Leaper, 2003), both subtle and overt discrimination in STEM fields (Agars, 2004; Barres, 2006; Benokraitis & Feagin, 1995; J. R. Steele, James, & Barnett, 2002), as well as greater career options for women over men in non-STEM fields (Wang, Eccles, & Kenny, 2013). Research also suggests that the gender gap in math performance has decreased over time (from the 1970s to 1990s; see Miller & Halpern, 2014), which runs contrary to the hypothesis of intrinsic, and therefore theoretically stable, sex differences in math ability. However, despite this decrease across the years, there is evidence that a male advantage remains (Miller & Halpern, 2014) that must be explained. Of relevance to the present paper, a growing body of research has provided strong evidence for the power of stereotypes to impact not only the orientation of parents and teachers, but also women themselves through a process termed *stereotype threat*.

The primary goal of this paper is to review the current literature examining the emergence of math-gender stereotypes and the impact of stereotype threat on girls' math test performance from early elementary school to middle school. We start by defining stereotype threat and then provide a brief review of the findings examining the impact that stereotypes can have on the math test performance of women. We then provide a brief overview of how and when children develop gender stereotypes with a focus on both explicit and implicit stereotypes about mathematics. Next, we review the limited research conducted to date examining the effect that stereotype threat can have on girls' academic performance in the laboratory and in the classroom. We conclude by outlining possible interventions that can help to empower girls in stereotype threatening situations, building on current findings with both children and adults.

Stereotype threat and women's math performance

Stereotype threat is a situation-specific threat that occurs in contexts where members of negatively stereotyped groups risk the possibility of inadvertently confirming the stereotype about their group. As C. M. Steele and Aronson (1995) note, "the existence of such a stereotype means that anything one does or any of one's features that conform to it make the stereotype more plausible as a self-characterization in the eyes of others, and perhaps even in one's own eyes" (p. 797). The possibility of confirming the negative stereotype can produce a disruptive concern that can interfere with performance in the stereotyped domain, ironically leading to decreased performance in, or orientation towards, the domain. Extensive research on stereotype threat processes have been conducted with women in STEM fields and have conclusively demonstrated that women's math test performance (Ambady, Paik, J. R. Steele, Owen-Smith, & Mitchell, 2004; Cadinu, Maass, Rosabianca, & Kiesner, 2005; Inzlicht & Ben-Zeev, 2000; Inzlicht & Schmader, 2012; Schmader, 2002; Schmader & Johns, 2003; Schmader, Johns, & Forbes, 2008; Smith, 2004; Spencer, C. M. Steele, & Quinn, 1999) and attitudes towards math-related fields (Davies, Spencer, Quinn, & Gerhardstein, 2002; J. R. Steele & Ambady, 2006) can be negatively impacted by contexts that elicit a concern with confirming a negative stereotype about women in these domains (see Davies & Spencer, 2005; Inzlicht & Schmader, 2012; C.M. Steele, Spencer, & Aronson, 2002; J. R. Steele, Reisz, Williams, & Kawakami, 2007, for reviews; for a recent extension to abstract reasoning ability, see Régner et al., 2010). More recent studies have demonstrated that stereotype threat also impairs stereotyped students from building abilities in the first place (for a review, see Appel & Kronberger, 2012), by interfering with the encoding of material (Taylor & Walton, 2011), note taking and test preparation (Appel, Kronberger, & Aronson, 2011), the comprehension of rules (Rydell, Rydell, & Boucher, 2010), and the use of efficient strategies (Rydell, Shiffrin, Boucher, Van Loo, & Rydell, 2010).

Research suggests that women's susceptibility to stereotype threat can be moderated by a belief in or endorsement of this stereotype (Schmader, Johns, & Barquissau, 2004) but performance can also be affected by automatic gendered associations that women have developed with this domain (Kiefer & Sekaquaptewa, 2007a, 2007b; Nosek, Banaji, & Greenwald, 2002; Nosek et al., 2009; see also Galdi, Cadinu, & Tomasetto, 2014; Steffens, Jelenec, & Noack, 2010). In recent years new tools have been developed to move beyond examining explicit beliefs – such as self-reported attitudes and stereotypes – to instead examining automatic responses using implicit measures. One of the more extensively used tools that has been created is the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998; Greenwald, Nosek, & Banaji, 2003) which has been used to assess people's automatic responses to male stereotyped domains such as mathematics and female stereotyped domains such as literature. Implicit stereotyping refers to "strong cognitive associations between a social group and stereotypic attributes" (Kiefer & Sekaquaptewa, 2007a, p. 13), and these associations may or may not correspond to people's explicit knowledge and/or endorsement of stereotypes. Assessing implicit stereotypes can be accomplished by having participants complete a computer task and collecting their reaction time data. In a stereotyping IAT (see for example, Nosek et al., 2002, for more details on this measure), after two training blocks, participants are presented with a first critical block in which they are asked to quickly sort individually presented stimuli, using one key for items depicting the categories math and male and another key for items depicting literature and female. In a second critical block (with the order typically counterbalanced between participants), participants are asked to sort individually presented stimuli using one key for items depicting math and female and another key for items depicting literature and male. Reaction times for the two critical blocks are collected and compared.

If participants automatically stereotype, they should be quicker to associate math with male and literature (or even a neutral category) with female as compared to the reverse pairing. Research with adults has repeatedly shown that this tends to be the case, for both male and female university students (Nosek et al., 2002) and even for women enrolled in university-level calculus courses (Kiefer & Sekaquaptewa, 2007a) – and this occurs in the absence of explicit endorsement of any gender stereotype. More importantly, recent research has suggested that these associations have the potential to hamper women's identification with this domain. Although it is not possible to conclusively draw causal links, Nosek et al. (2002) found that the more women implicitly stereotyped math relative to arts, the less positive they were towards mathematics and the worse they performed on a standardized test of math ability. In addition, a study conducted by Nosek et al. (2009) across thirty-four countries found a reliable relationship between nation-level implicit gender stereotyping in science and national sex differences in the math achievement of eighth graders (13-14 years old).

Gender stereotyping in childhood

If stereotyping and stereotype threat contribute to women's underrepresentation and underperformance in STEM fields, why is it that girls are not similarly affected by these processes? Or are they? Although we know that children tend to self-segregate based on sex from early elementary school (Bem, 1996; Dumas, Huguet, Monteil, Rastoul, & Nezlek, 2005) and are very aware of sex-typed male and female activities from between 3 and 6 years of age (Eisenberg, Martin, & Fabes, 1996), there is far less experimental research examining gender stereotyping about academics and the consequences of these stereotypes among young children (Ambady, Shih, Kim, & Pittinsky, 2001; Galdi et al., 2014; Ganley et al., 2013; Huguet & Régner, 2007, 2009; Muzzatti & Agnoli, 2007; Neuville & Croizet, 2007; J. R. Steele, 2003; Tomasetto, Alparone, & Cadinu, 2011), and the evidence for when and how children develop gender stereotypes about mathematics tends to provide mixed results. Below, we review some of the literature examining math-gender stereotyping in childhood.

Preschool to grade 3 (2-8 years old)

Children become aware of gender and ethnic categories in early childhood and are able to accurately discriminate between males and females by 2 years of age (Huston, 1987). Children are also able to identify people of different ethnicities between 3 to 5 years of age (Aboud, 1988; Hirschfeld, 1996). Moreover, there has been evidence suggesting that, as early as first and second grade, children believe that boys are better than girls in mathematics (Cvencek, Meltzoff, & Greenwald, 2011; del Rio & Strasser, 2013; Lummis & Stevenson, 1990) and also express the belief that mathematics performance is more relevant to boys' rather than girls' self-concepts (Entwistle, Alexander, Pallas, & Cardigan, 1987). However, other research has not found similar evidence for this math-gender stereotyping in early childhood. For example, Ambady, Shih, Kim, and Pittinsky (2001) found that children from 3 to 13 years of age reported no gender differences on average in math. Likewise, Galdi et al. (2014) found that 6 year old children did not endorse the math-gender stereotype but rather manifested gender ingroup favoritism (i.e., girls and boys reporting higher math abilities for their own gender group).

Upper elementary school (grades 3-6, 8-12 years old)

During upper elementary school between the ages of 8-10 years, children begin to incorporate abstract concepts into their representations, such as the concept of masculinity and femininity (Eisenberg et al., 1996; Martin, Wood, & Little, 1990). After 7 years of age most children are able to incorporate individuating information into their social judgments (Martin et al., 1990). By the time children are 9 or 10 years old, their gender stereotypes begin to resemble those held by adults (Muzzatti & Agnoli, 2007; Steffens et al., 2010), although gender ingroup favoritism may still prevail (Huguet & Régner, 2009; Passolunghi, Ferreira, & Tomasetto, 2014). For example, Martinot and Désert (2007) found that children aged 9 to 12 years reported that girls do better than boys in math.

Middle school (grades 6-8, 12-14 years old)

Children's gender identity undergoes significant transformation as they approach adolescence and gender differences in mathematics achievement begin to emerge (Hyde, Fennema, & Lamon, 1990; see also PISA data, OECD, 2012). In Steffens et al. (2010), middle-school children reported beliefs consistent with the math-gender stereotype. However, Passolunghi et al. (2014) found that 8th grade boys displayed counter-stereotypic beliefs, and girls believed boys and girls to be equally competent in the mathematics.

Thus, research examining the acquisition of math-gender stereotypes in childhood provides many contradictory findings, preventing any firm conclusion (for a similar conclusion about stereotype threat susceptibility, see Ganley et al., 2013). This may be due to a number of factors, for example the diversity of self-report measures used from one study to another. As outlined by Martinot and Désert (2007), most studies did not distinguish between children's awareness of a stereotype (knowing what people in general think about abilities of a typical boy and a typical girl) and their endorsement of the stereotype (children's own personal beliefs about the abilities of a typical boy and a typical girl). This is problematic because this distinction has proved critical in the area of prejudice and discrimination among adults (e.g., Devine 1989; Devine & Elliot 1995). Furthermore, the age subgroup of the targets mentioned in the items also matters. As predicted by the stereotype stratification model presented below, children may respond very differently to the same question depending on whether the target falls into their age subgroup ("girls and boys") versus a different age subgroup ("men and women"). In addition, the measures taken at the explicit level (self-reports) may not correspond to automatized or implicit gender stereotypes. This is another important issue, because social desirability may interfere with the measurement of explicit responses; it may therefore not be sufficient to focus on consciously-accessible evaluations when examining the development of stereotype about mathematics, because adults as well as children may be unaware of, or unwilling to report, all of their thoughts and feelings (for a recent illustration in adults, see Enea-Drapeau, Carlier, & Huguet, 2012).

Stereotype stratification and the performance paradox

In an attempt to better understand how academic gender stereotypes emerge and begin to impact children's orientation towards academic domains, J. R. Steele and her colleagues (J. R. Steele, 2003; J. R. Steele, Williams, & Mills, 2010; J. R. Steele, Williams, Reisz, Loi, & Shapiro, 2014) have put forth a theory of stereotype stratification and provided support for this theory across several studies with predominantly White North American children in early elementary school. Girls are presented with discrepant information about gender and mathematics; they might notice that in the greater society women are underrepresented in STEM fields and yet they may be presented with a daily reality that girls in elementary school are performing well in this domain. To resolve this discrepancy, girls might stratify the stereotype, developing it specifically about an age subgroup to which they do not belong. According to J. R. Steele (2003), "when presented with stereotypical information about females and mathematics, girls may view the stereotype as being true for women (i.e., the age subgroup to which they do not belong) but not true for girls (i.e., the age subgroup to which they do belong)" (p. 2590). By developing the stereotype in this way, girls might be protected from some of the potentially deleterious effects of this stereotype in the short term, but might face difficulties staying identified with this domain in the long-term, as they make the transition into womanhood and hence into the negatively stereotyped group.

To examine whether girls were developing the stereotype in this way, J. R. Steele (2003, Study 1) asked girls in early elementary school to simply rate how good most boys, girls, men, and women are at mathematics as well as how much most boys, girls, men, and women like this domain. Consistent with the possibility that girls might develop a stereotype specific to adults, girls in this study rated men as liking math more and as being more capable in math relative to women, but rated girls and boys as being comparable in their interest and ability in this field. In a second study, a new sample of girls, with a mean age of 7 ½ years, were asked to draw a picture of either an adult or a child mathematician. In line with the expectations, girls who were asked to draw a child mathematician tended to draw a girl, but girls who were asked to draw an adult mathematician tended to draw a man (J. R. Steele, 2003, Study 2). In the same vein, Martinot, Bagès, and Désert (2012) found that French fifth graders (10-11 years old) were aware of the math-gender stereotype when the stereotyped targets were adults but not when the targets were children and young adolescents (i.e., children believed that people think that girls succeed as well as boys in math).

Children's implicit stereotypes

More recently, J. R. Steele and her colleagues (J. R. Steele et al., 2010; J. R. Steele et al., 2014) have specifically focused on the emergence of implicit gender stereotypes about academics. Given the fact that implicit stereotypes might present a hidden barrier for women in this domain (Kiefer & Sekaquaptewa, 2007a, 2007b; Nosek et al., 2002; Nosek et al., 2009), and that little is known about when these associations are acquired, J. R. Steele and her colleagues were first interested in knowing whether children are gender stereotyping academics implicitly and/or explicitly. Building on research that girls begin to lose confidence in mathematics around the age of 9 years, the findings that Caucasian girls in Italy were susceptible to stereotype threat by the age of 10 years (Muzzatti & Agnoli, 2007), and the earlier evidence of stereotype stratification (J. R. Steele, 2003), J. R. Steele et al. suspected that children would have acquired a global stereotype – reflected in their implicit associations and explicit ratings – by mid- to late-elementary school (around ages 9 to 11 years). However, building on the theory of stereotype stratification, they also suspected that an age-specific stereotype would begin to emerge even earlier – specifically by 7 or 8 years of age.

To examine these possibilities, in a first study these researchers examined implicit stereotyping in early elementary school – among children who ranged in age from 5 to 8 years of age, with a mean age of 7 years. To assess implicit stereotyping, children were provided with a child-friendly version of the IAT (or ch-IAT) to complete. This IAT was similar to the adult version of the measure that was described earlier, with the exception that it was completely picture-based. In the stereotype-consistent critical block for this ch-IAT, children were presented with previously viewed pictures of boys and girls as well as pictures depicting math and reading/writing, and they were asked to press one key when they saw a boy or a picture depicting math and another key when they saw a girl or a picture depicting reading and writing. In the counterstereotypical critical block, the placement of the math and reading/writing pictures were reversed and participants were again presented with all of the previous pictures and asked to press the appropriate key. In order to test for stereotype stratification, roughly half of the participants saw pictures of men and women instead of pictures of boys and girls – allowing the researchers to assess whether implicit stereotyping was specific to child or adult targets. In addition, to control for order effects, the stereotypical and counterstereotypical critical blocks were counterbalanced across participants. Children's reaction times within each critical block were collected and a D-score was calculated as outlined by Greenwald and his colleagues (2003). Children also completed the explicit measure of stereotyping from J. R. Steele (2003), in which they were asked to rate the ability of most boys, girls, men, and women for mathematics.

Unlike the findings from J. R. Steele (2003), this sample of girls did not show any evidence of stereotype stratification explicitly. In fact, they tended to rate both girls and women as having more ability in mathematics relative to boys and men respectively. Taken alone, this finding might suggest that girls had not developed the traditional gender stereotype for this domain. This finding could reflect changing times, as this research was conducted more than a decade after J. R. Steele (2003). However, when examining their implicit responses, a different pattern emerged. Girls who had seen pictures depicting men and women were faster to associate male with math and female with reading and writing relative to girls who had seen pictures depicting boys and girls; in the former case they were automatically gender stereotyping these domains whereas in the latter case they were not. If anything, when presented with pictures of boys and girls, girls were faster to associate females with mathematics and males with reading and writing relative to the reverse pairing. The automatic associations of these early elementary school-aged girls therefore revealed an age-specific stereotype that was consistent with the theory of stereotype stratification. Instead of acquiring a global stereotype about males and mathematics and females and reading/writing, they had acquired this stereotype only about adults (cf. Galdi et al., 2014).

In a second study J. R. Steele et al. (2014) examined the implicit and explicit stereotyping of older children in grades 3 through 6, with a mean age of about 10 years. Explicitly girls again tended to rate girls as being better than boys in mathematics; however this older sample of girls rated men and women as having equal abilities in this domain. Importantly, at this age girls implicitly stereotyped this domain regardless of whether they were shown pictures of boys and girls or men and women in the implicit measure (see also Cvencek et al., 2011). In either case, older elementary school girls were quicker to associate math with male and reading and writing with female relative to the reverse pairing. Thus, despite the fact that in this sample older elementary school-aged girls did not endorse a gender stereotype explicitly, their implicit responses suggest that stereotypical associations had been acquired. Although limited by the cross-sectional nature of this research, these findings hint at the possibility that academic stereotypes about mathematics might first be acquired implicitly in a way that is initially specific to men's and women's (not girls' and boys') abilities in these domains. As children approach adolescence, these stereotypical associations become more global and therefore have the potential to affect girls' orientation and performance in math and science.

In partial contrast to these findings, Cvencek et al. (2011) found evidence (using the ch-IAT with child targets) of an implicit math-gender stereotype as early as second grade, with research by Galdi et al. (2014) suggesting that for girls (but not boys) these associations might emerge as early as the first grade. It seems possible therefore that implicit math-gender stereotypes about children might emerge earlier in different contexts. Even in these contexts implicit math-gender stereotyping of adults may precede implicit math-gender stereotyping of children, a possibility worthy of further investigation. In addition, Steffens et al. (2010) found (also using the ch-IAT) that implicit gender stereotyping predicts academic math self-concept, math achievement, and enrollment preferences above and beyond explicit math-gender stereotypes, for girls as early as 9 years of age (see also Passolunghi et al., 2014). As a whole this research suggests that academic stereotypes begin to form from an early age and have the potential to adversely affect girls' orientation towards and performance in mathematics.

It is worth noting that all of the research examining children's implicit math-gender stereotyping to date has made use of measures that contrast math with language or arts. Future research using measures that decouple these two domains (e.g., Steffens & Jelenec, 2011) would help to further our understanding of how these implicit academic stereotypes emerge, what they predict, and how they might be combatted. In addition, research focused on the malleability of these beliefs is necessary. Research by Galdi et al. (2014) suggest that even a brief exposure to a counterstereotypical picture (depicting a girl answering a math question correctly and a boy answering incorrectly) can eliminate first grade girls' implicit gender stereotyping. Future research will be needed to determine whether children's implicit stereotypes are as malleable at other stages of development.

Stereotype threat and girls' math performance

One important question to arise from these literatures is whether self-relevant stereotypes affect the behavior of girls from a young age. Initial evidence of stereotype threat in young girls completing a math test was found by Ambady et al. (2001). These authors examined the developmental course of susceptibility to stereotypes with a sample of Asian-American girls, ranging in age from Kindergarten to grade 8 (ages 5 to 13). Identity was activated for participants from Kindergarten to grade 2 (ages 5 to 7) by having them color one of three randomly selected pictures, because many children at this age are still learning to read and to write. In the Ethnic identity activation condition, participants were asked to color a picture depicting two Asian children eating with chopsticks out of rice bowls. In the Gender identity activation condition, participants were asked to color a picture of a girl holding a doll. In the control condition, participants were asked to color a landscape scene. In order to keep the experimenter blind to the condition, participants were asked not to show the picture to the experimenter. Identity was activated for participants from grades 3 to 8 (ages 8-9 to 13-14) by having participants fill out one of three randomly selected questionnaires. In the Ethnic identity activation condition, participants were asked to answer questions related to ethnicity such as whether they spoke a foreign language at home. In the Female identity activation condition, participants were asked to answer questions related to gender such as whether most of their friends were boys or girls. In the control condition, participants were asked to answer neutral questions such as their favorite season. After the participants had completed the manipulation task, they were given a math test consisting of questions taken from a standardized math test, the Iowa Test of Basic Skills, appropriate to their particular grade.

Children's knowledge of stereotypes was also assessed both directly and indirectly. To indirectly assess gender stereotypes, participants were told: "There were many good students in my high school, but one of my classmates stood out from the rest. This student got A*s* in every subject, but was especially good at math. This student could figure out problems that even the teachers couldn't solve. One time, the student entered a state math contest and got a perfect score!" Participants were then asked to repeat the story and the experimenter noted whether they used the pronoun "he" or "she". To assess ethnicity stereotypes indirectly, participants were shown a picture of an Asian and a Caucasian girl and were told: "Sarah is 6 years old and is already very good at math. Which of these girls do you think she probably is?" The participant's choice was then recorded. Participants were also given a direct stereotype awareness task in which they were explicitly asked the questions: "Are boys better at math, girls better at math or the same?" and the question "Are Asians better at math, white people better at math or are they the same?"

On the indirect measures, girls of all 3 age groups were more likely to identify the Asian child as being significantly more likely to be good at mathematics than the Caucasian child, indicating awareness of the sociocultural stereotypes. On the indirect measure of gender stereotype awareness, the youngest and oldest groups were slightly — but not significantly — more likely to assume the outstanding math student was a boy than a girl, but the third through fifth graders (10-11 years old) were slightly more likely to identify the student as a girl rather than a boy. No significant differences were found on the direct explicit stereotype awareness measures. When asked whether boys or girls were better at math or if they were all the same, the majority of children, (75%) regardless of their ages, responded that boys and girls were the same. There were also no significant differences in their explicit opinions about whether Asians were better at math, Caucasians were better at math, or the two groups were the same. Regarding performance, results revealed that the oldest participants (i.e., participants in middle school, 11-14 years old) scored highest when their Asian identity was made salient and lowest when their gender identity was made salient compared to those in the control condition.

Of particular interest here, the negative gender stereotype was not detected at the explicit level in Ambady et al.'s (2001) study, suggesting that students' may have acquired the stereotype despite not explicitly endorsing it (see also Huguet & Régner, 2009, later in this paper). The most surprising finding was that the youngest participants (i.e., lower elementary school, K-2) also showed the same pattern of results, scoring higher when their Asian identity was activated by the coloring task and lower when their female identity was activated by the coloring task compared to controls. Participants in the upper elementary school (grades 3-5; ages 8-11), however, showed the reverse trend. They scored higher on the math test when their female identity was activated than when their Asian identity was activated or when no particular identity was activated; a finding consistent with the ingroup bias typically found in both sexes on a variety of tasks in children of this age (e.g., Kaminski & Sheridan, 1984; Powlishta, 1995; J. R. Steele, 2003; Yee & Brown, 1994). Thus, this study showed that the mathematical performance of even very young girls can be affected by the subtle activation of sociocultural stereotypes (see also Shenouda & Danovitch, 2014, who showed that 4-year-old girls were significantly slower to solve a visual-spatial task when their gender identity was activated relative to when it was not). The effects of threat associated with negative stereotypes in the domain of quantitative performance (Aronson, Quinn, & Spencer, 1998; Spencer et al., 1999; C. M. Steele, 1997) occur quite young, but the protective effects of subtly activated positive stereotypes also seem to occur at the same age.

A second study using a similar methodology examined the influence of stereotype activation on the academic performance of Asian-American boys (Ambady et al., 2001). While we are focusing on the performance of girls in this paper, the results for boys also underscore the vulnerability of children to prevailing sociocultural stereotypes. In line with dominant sociocultural stereotypes that Asians are particularly good at math and that boys are better at math than are girls, both the youngest group and the oldest group of boys in the gender and ethnicity identity activation conditions performed better than boys in the control condition. The middle group of boys, similar to the Asian-American girls in the previous study, performed best in the gender identity activation condition.

Although the above findings show that the mathematical performance of even very young girls can be affected by the subtle activation of stereotypes, Ganley et al. (2013) failed to find stereotype threat effects at different age levels (from 9 to 18 years old) across three studies. This may not be surprising, however, as two of the studies (studies 2 and 3; see below for Study 1) lacked a no-stereotype threat control group needed to experimentally test stereotype threat effects. Even if the math-gender stereotype was not explicitly activated in the control condition, the test was still presented as a math test. This could be sufficient for the stereotype to be implicitly activated, resulting in seemingly null stereotype threat effects since no other instructions were delivered to reduce this threat (for a similar argument about null effects in stereotype threat research, see C. M. Steele & Davies, 2003). As demonstrated by Chan and Rosenthal (2014), secondary school girls with higher-working memory are better equipped to resist stereotype threat in math. Therefore, the fact that school girls may or may not experience stereotype threat depending on working memory availability may also help to explain why this threat is not systematically detectable in children (see also Régner et al., 2010, for similar findings in adults). The fact that individual differences in working memory capacities moderate stereotype threat should therefore receive further attention through future research.

Stereotype threat in the classroom

The question that now arises is exactly how can girls be affected by stereotype threat in the absence of a verified difference on standardized math tests in this school-age population (Hyde & Linn, 2006)? Faced with this new discrepancy, Huguet and Régner (2009) suggested that the negative gender stereotype may actually operate by maintaining schoolgirls' performance at a suboptimal level, yet this effect may not be strong enough in children to systematically produce the gender gap. Put differently, the absence of a gender gap in the school-aged population should not be taken to mean that stereotype threat is not operating at all. This is of great practical significance. Indeed, teachers and policy makers may wrongly infer the absence of stereotype threat from the lack of any gender gap in math tests and/or math exams. This inference, in turn, may lead to the problematic conclusion that there is no reason to worry about stereotype threat in the classroom. Instead, Huguet and Régner (2007, 2009) showed that stereotype threat in schoolgirls can be found in the school context when being tested either individually or collectively in quasi-ordinary classroom setting.

In a first study, these authors examined whether stereotype threat occurred among French middle-school girls (10-12 years old) when they are simply led to believe that the task at hand measures mathematical skills. To that end, the authors used a modified version of the Rey-Osterrieth Complex Figure (ROCF) recall memory task (Akshoomoff & Stiles, 1995; Kirkwood, Weiler, Bernstein, Forbes, & Waber, 2001; Rey, 1941). This task – which actually does not measure math skills – is still in widespread use today for neuropsychological assessment (of adults as well as children), especially when perceptual organization, visuospatial constructional ability, planning, and visual memory are being evaluated. The ROCF task is a two-dimensional line drawing that has no particular meaning and that can be presented as either a "geometry test", a "memory game", or a "drawing test" (Huguet & Monteil, 1995; Huguet, Brunot, & Monteil, 2001), at least with children. It was therefore well-suited for subtly and indirectly activating the negative gender stereotype. Participants were met individually by a same-gender experimenter in one of their regular classrooms. They were told that the task they would be given might help develop a new geometry test for a textbook (Geometry condition) versus a new game for a fun magazine (Memory game condition). Within each gender, students were assigned at random to one of the two conditions (Geometry Test vs. Memory Game). They were given 50 seconds to learn the ROCF task and then 5 min to reconstruct it from memory on paper. Recall performance was measured in terms of both the number and quality of the units reproduced from the complex figure.

Results revealed that whereas girls underperformed (i.e., recalled fewer units) relative to boys in the geometry condition, they outperformed them in the memory-game condition. This study thus complements research reviewed above, by providing evidence of stereotype threat in schoolgirls who were simply led to believe that the task being performed measured mathematical skills. The negative gender stereotype was activated both implicitly and indirectly by means of task characterization, which was sufficient for a performance deficit to occur in the stereotype-threat condition. However, these findings left a crucial question unanswered: can stereotype threat be found in schoolgirls under more ordinary classroom circumstances? The fact that girls working alone exhibited a performance deficit when they believed that the task measured mathematical skills is one thing. Whether this deficit occurs under conditions close to those found in an ordinary classroom (i.e., classmates present) is another.

This issue was addressed by Huguet and Régner (2007) in a second study. French students (again aged 10-12 years) were met *collectively* in one of their regular classrooms. They were seated separately to prevent cheating and told that the task was designed to evaluate their “ability in geometry” versus their “ability in drawing”. “Drawing” was used (rather than “memory game”) to see whether the findings of Study 1 could be replicated when the stereotype-irrelevant condition implied an academic subject that is part of the curriculum (in France, drawing is a mandatory subject at this age). As in Study 1, results indicated that whereas girls performed less well than boys in the geometry condition, they outperformed them in the no-threat (drawing) condition.

This pattern offers direct evidence that stereotype threat in schoolgirls can be found with students in conditions close to ordinary classroom circumstances where male and female classmates are present.

Stereotype threat and counter-stereotypic beliefs

Another remaining question that is of great importance for teachers is whether stereotype threat operates in schoolgirls who explicitly deny the negative gender stereotype. As illustrated by several studies described earlier in this paper (Ambady et al., 2001; J. R. Steele, 2003; J. R. Steele et al., 2010), schoolgirls tend to report either that girls are better than boys at math or that boys and girls are the same. However, no study had tested whether girls' beliefs about the two genders' math ability *moderate* their susceptibility to stereotype threat. Schmader et al. (2004) offered evidence for this moderation in women, with lower stereotype threat susceptibility in those denying the negative gender stereotype. Huguet and Régner (2009) directly addressed this issue in children. French students (10-12 years old) were met collectively in their regular classrooms and were either told the ROCF task would measure their ability in geometry or in drawing. Students' stereotypic-related beliefs were also assessed using items adapted from Schmader et al. (2004). Participants rated the two genders' geometry ability in their age group (''In general, what is the geometry ability of girls your age?"; ''In general, what is the geometry ability of boys your age?"). Students also self-evaluated in geometry (and drawing) compared to "most of (your) classmates" (hereafter referred to as "comparative judgments").

Results first indicated that the stereotype threat pattern clearly emerged on performance. As in Huguet and Régner (2007, Study 2) geometry labeling led to worse performance for girls compared to drawing labeling but the labeling condition made no difference for the performance of boys. In addition, whereas girls underperformed compared to boys in the geometry labeling condition, they outperformed boys in the drawing labeling condition. Second, girls' beliefs about the two genders' geometry ability in their age group were on average counter-stereotypic. Girls reported that girls were better than boys at math, whereas boys reported exactly the reverse (while girls and boys actually obtained similar math/geometry grades). Despite these counter-stereotypic beliefs, girls (but not boys) underestimated their own ability in geometry (but not in drawing), as indicated by their comparative judgments. These findings may be interpreted in terms of stereotype internalization, in line with Eccles et al.'s (1983) expectancy model, and more particularly with the findings of Jacobs, Lanza, Osgood, Eccles, and Wigfield (2002), who found gender differences favoring boys in self-perceptions of math abilities in early elementary school. Above all, Huguet and Régner (2009) showed that students' beliefs about the two genders' math ability *did not* moderate girls' susceptibility to stereotype threat. Thus, even girls who denied the negative gender stereotype suffered from it when they simply believed that the task they were going to take measured geometry skills. Because stereotype threat is not necessarily detectable in students' *grades*, teachers, parents and policy makers may all take for granted that elementary- and middle-school girls are not susceptible to this effect, particularly when girls reject the negative gender stereotype. They may conclude that stereotype threat related interventions are therefore unnecessary. The findings mentioned here (Huguet & Régner, 2009) lead to the opposite conclusion: neither the absence of gender differences in math performances, nor girls' expressed counter-stereotypic beliefs can be taken as sufficient evidence that stereotype threat is not operating. Appropriate interventions should therefore be viewed as the 'default option' when aiming for true gender equality in math and science achievement.

Possible interventions: Empowering girls

One promising practical finding from Ambady et al.'s work is that both younger as well as older girls showed performance boosts when an alternative identity associated with positive stereotypes in the quantitative domain was subtly activated (for examples of the potentially deleterious effects of positive stereotypes that are blatantly activated, see Cheryan & Bodenhausen, 2000; Siy & Cheryan, 2013). Thus, possessing an alternative identity associated with positive stereotypes might buffer girls from the negative stereotypes associated with their gender. This finding has important implications for the types of interventions that might be designed to make girls less vulnerable to negative gender stereotypes in the domains of mathematics and science. Interventions could be designed that facilitate the development of alternative positive stereotypes associated with mathematical performance for girls. For instance, girls might be exposed to the notion that girls in their school or girls who have taken a specific "special" math class are particularly good at mathematics.

It is also noteworthy that the pattern of results for children in upper elementary school (8-10 years old) was quite different from that of older and younger children. In upper elementary school, girls' and boys' quantitative performance improved when their gender identity was activated as compared to when their ethnic identity was activated or when no identity was activated. One explanation for these results is that at this stage children are extremely chauvinistic about their gender identity and feel that their own sex is superior to the other (Kaminski & Sheridan, 1984; Powlishta, 1995; Yee & Brown, 1994). Thus, superior performance associated with gender identity activation might be associated with this chauvinism, at least at this age. One intervention to combat stereotype threat effects as girls age, therefore, might be to devise methods to enable them to hold onto this chauvinism instead of relinquishing it in middle school. However, such chauvinistic attitudes may not always be sufficient, and may have corresponding negative social consequences, especially with children entering adolescence (11-13 years of age; see Huguet & Régner, 2009).

The ability to call to mind positive role models that can be harnessed in appropriate situations might also serve as a way to combat negative stereotypes (Bagès & Martinot, 2011). Several studies conducted with adults have found that learning about another woman who excelled in math alleviated women's performance deficits under stereotype threat (Marx & Roman, 2002; McIntyre, Lord, Gresky, Ten Eyck, Frye, & Bond Jr., 2005; McIntyre, Paulson, & Lord, 2003), exactly as one would expect if female participants had engaged in upward-comparison assimilation (for this notion, see Huguet, Dumas, Marsh, Régner, Wheeler, Suls, Seaton, & Nezlek, 2009; Mussweiler & Strack, 2000; Wheeler & Suls, 2007). In children, positive role models also proved beneficial for both gender groups, provided that the success of the role models was attributed to work and effort instead of math giftedness (Bagès & Martinot, 2011). Consistent with this idea, Good, Aronson, and Inzlicht (2003) showed that girls (12-13 years old) who were encouraged by mentors (college students) at different points of the academic year to view intelligence as malleable earned significantly higher math standardized test scores than girls not exposed to these multiple encouragements. Ganley et al. (2013, Study 1) failed to replicate this interesting finding; however unlike Good et al. (2003), Ganley et al. relied on a single exposure to math intelligence as a malleable entity, which may not have been sufficient to change students' representation of math intelligence as a fixed entity—the default option, at least in Western cultures (Mugny & Carugati, 1989). In line with this explanation, Ganley et al. (2013) found that boys outperformed girls even when math intelligence was presented as malleable.

More simple and straightforward interventions have also proven to be effective at buffering young school girls from stereotype threat. For example, Galdi et al. (2014) found that girls in first grade performed significantly better on a math test after briefly viewing a picture of a girl correctly answering a math question and a boy providing an incorrect answer, as opposed to when the gender of the characters was reversed (i.e., the girl was incorrect and the boy was correct), and this was mediated by girls' implicit math-gender stereotyping following the picture intervention. Master, Cheryan, and Meltzoff (2014) also showed that female teachers can help to reduce adolescent girls' concerns about being negatively stereotyped in computer science courses once stereotype threat has been activated.

Another question that arises concerning positive role models is what determines their salience in the classroom. Based on findings showing that college women's math performance was lower in a mixed-gender setting with a majority of males than in a same-gender setting (Inzlicht & Ben-Zeev, 2000; Sekaquaptewa & Thompson, 2003), Huguet and Régner (2007, Study 2) reasoned that the salience of successful role models for girls should be higher in a same-gender setting than in a mixed-gender setting. In this study, classrooms were divided into either two mixed-gender or two same-gender subgroups of 10 to 14 students. As described earlier, students were either told the ROCF task would measure their ability in geometry or in drawing. To capture the salience of positive gender role models (i.e., high-math-ability female classmates for girls and high-math-ability male classmates for boys), students were asked to nominate the best and worst math achievers in their class.

Results first revealed that girls' performance deficit (i.e., the stereotype threat pattern) occurred in mixed-gender groups but not in same-gender groups. In addition, compared with the mixed-gender groups, the same-gender groups were associated for girls in the stereotype threat (geometry) condition with greater accessibility of positive role models (i.e., female classmates who excel in math), at the expense of both stereotypic ingroup and outgroup members (i.e., low-math-achievement girls and high-math-achievement boys). Finally, the greater accessibility of positive role models mediated the impact of the activated stereotype on girls' performance. It is noteworthy that the girls' tendency to nominate high-math-ability females was found in every condition except the one where they underperformed (i.e., geometry condition in the mixed-gender setting), and showed up especially in the mixed-gender setting when the task was said to assess drawing ability.

Huguet and Régner (2007) pointed out that these findings must not be taken as evidence of the merits of single-gender over coed education. First of all, although single-gender education may help prevent stereotypes from taking effect downstream (i.e., in testing situations), it is ineffective if not detrimental upstream (i.e., stereotype formation and propagation), which is obviously not satisfactory. As indicated by a myriad of findings in the social categorization literature (e.g., Cadinu & Rothbart, 1996; Dovidio, Glick, & Rudman, 2005; Gaertner & Insko, 2000; Otten & Moskowitz, 2000; Tajfel & Turner, 1979), putting individuals into separate groups typically strengthens (or even creates) stereotypes rather than reducing them and the consequences they trigger. Second, it is not the sheer presence of males that is problematic. In Huguet and Régner's (2007) Study 1, girls worked alone (i.e., in the absence of any members of the opposite gender), yet this arrangement did not prevent their performance deficit from showing up in the threatening condition. More recently, Pahlke, Hyde, and Allison (2014) analyzed 184 studies of more than 1.6 million students from around the world, and showed that single-sex education indeed does not educate girls and boys any better than coed schools.

In addition, separating the genders is not the only way to proceed at the practical level. Johns, Schmader, and Martens (2005), for instance, showed that teaching adult students about stereotype threat is an efficient means of reducing its detrimental effects in testing situations. This option is especially attractive, since it may also help people propagate counter-stereotypic views within their social network, including among their own children. Another interesting option comes from the features of real testing situations themselves, where both math and verbal tests are administered. Smeding, Dumas, Loose, and Régner (2013) showed that middle school girls (grades 7-8; 11-15 years old) performed better on a standardized math test when they first took a verbal test, probably because taking the verbal test (a domain in which girls are positively stereotyped) first increased their feelings of self-efficacy and/or performance expectancies. Since taking standardized tests comprising verbal- and math-related sections is a frequent practice in educational settings, ensuring that the verbal sections are completed before the math sections is a realistic intervention to support girls' educational aspirations through a reduction of bias in test scores in math. This ecological method seems even more interesting as it benefited girls' math performance without significant costs for boys' math or verbal performances. Likewise, Souchal, Toczek, Darnon, Smeding, Butera, and Martinot (2014) showed that another way to increase girls performance without harming boys performance is to orient students toward mastery goals (or learning *per se*) instead of performance goals (the motivation to compete and perform better than others). Research with adults and children further suggests that any action likely to heighten girls' levels of expectation (Cadinu, Maass, Frigerio, Impagliazzo, & Latinotti, 2003), to promote their self-affirmative thoughts prior to test taking (Cohen, Garcia, Apfel, & Master, 2006; Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Croizet & Després, 2003; see also Spencer, Fein, & Lomore, 2001), to teach them to individuate themselves (Ambady, et al., 2004) and facilitate the development of alternative positive stereotypes associated with math performance for girls (Ambady et al., 2001; Shih, Pittinsky, & Ambady, 1999), to increase the accessibility of positive and hardworking role models (Bagès & Martinot, 2011; Blanton, Crocker, & Miller, 2000; McIntyre et al., 2003), or to promote mastery goals (Souchal et al., 2014) represent valuable options.

Conclusion

In conclusion, the current paper provides evidence – from North America and Europe – that the prevailing negative gender stereotypes in the field of mathematics can have a deleterious effect on the math test performance of young girls. This research also supports the promising possibility that the context can be shifted and interventions can be introduced to help minimize or eliminate these effects. Future research should aim to further identify the developmental trajectory of these implicitly and explicitly held beliefs and importantly should focus on finding new ways that stereotype threat can be overcome. Building on this literature, we can strive to identify multiple ways to protect and optimize the attitudes and performance of our future scientists – regardless of their gender.

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