Women and Minorities in Science, Technology, Engineering and Mathematics

Upping the Numbers

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8. Women in mathematics: examining the hidden barriers that gender stereotypes can impose

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> So my best guess, to provoke you, of what's behind [women's underrepresentation in the science and engineering workforce] is that the largest phenomenon, by far, is the general clash between people's legitimate family desires and employers' current desire for high power and high intensity, that in the special case of science and engineering, there are issues of intrinsic aptitude, and particularly of variability of aptitude, and that those considerations are reinforced by what are in fact lesser factors involving socialization and continuing discrimination.
>
> Lawrence H. Summers, President of Harvard University, 14 January 2005

Why are there fewer women than men pursuing and succeeding in prestigious careers in math and scientific domains? This question has captured the attention of researchers and the general public alike. Gender-based discrimination in the workplace is illegal, educational opportunities for women in the sciences seem abundant, and educational reforms have been introduced to help ensure that systematic biases are eliminated. So why is there not an equal number of men and women in top positions in these fields?

At a recent conference designed to discuss issues around diversifying the science and engineering workforce, the president of Harvard University at the time, Lawrence Summers, shared some of his thoughts on the matter. While acknowledging that gender socialization and discrimination might play some role in this gender discrepancy, Summers argued that there were two more influential factors. The first, he suggested, was women's relative lack of drive to put in the long hours needed to succeed in prestigious and lucrative positions:

> The most prestigious activities in our society expect of people who are going to rise to leadership positions in their forties near total commitments to their work . . . it is a fact about our society that that is a level of commitment that a much higher fraction of married men have been historically prepared to make than of married women.

Importantly, the second most central factor, he argued, was women's lesser intrinsic aptitude 'at the high end' of the mathematical ability spectrum. Although his views were not well received by many of those attending the conference and are not completely supported by scientific facts[1], these comments remain representative of a stereotype that continues to permeate our society: the belief that women are simply not as good as men in math and scientific domains.

Gender disparity in the representation of men and women in mathematics, engineering and the physical sciences is indisputable (Crocker et al., 1998; Peter and Horn, 2005; National Science Foundation [NSF], 2004; Stangor and Sechrist, 1998). According to some available statistics, women constitute only about 10 percent of the physical science, math and engineering workforce (C.M. Steele, 1997; Tietjen, 2004), and occupy only 8 percent of tenured and tenure-track positions in mathematics departments (Ripley, 2005) and 13 percent of the positions in chemistry departments (Marasco, 2005) at the top 50 research universities in the USA. Recent statistics at the undergraduate level reveal an increase in the number of women pursuing degrees in math and the physical sciences, and yet women still represent only a fraction of these majors relative to men (Peter and Horn, 2005). According to a 2004 report by the National Science Foundation, roughly 20 percent of the undergraduate and doctoral degrees in physics and engineering were awarded to women. Such facts suggest that the trends in underrepresentation in employment may continue for some time.

Although women's underrepresentation is a fact that cannot easily be disputed, the cause of this discrepancy is often readily up for debate. Contrary to what Summers seemed to suggest, a rich body of research by Jacquelynne Eccles, Janis Jacobs and their colleagues has pointed to the importance of social factors in this discrepancy (Eccles, 1987, 1994; Eccles and Jacobs, 1986; Jacobs and Eccles, 2000), and have particularly highlighted the importance of gendered socialization practices by parents in the domains of science and mathematics (Jacobs and Eccles, 1992; Jacobs et al., 2005; see also J. Steele and Barling, 1996; Tenenbaum and Leaper, 2003). For example, Jacobs and Eccles (1992) found that mothers' gender stereotypes influenced their children's expectations for success in mathematics, which, in turn, affected children's self-perceived ability in this domain. The researchers note that these expectations can lead to self-fulfilling prophecies in which children confirm the expectations of their mothers.

In addition, researchers have found continuing evidence that subtle and overt forms of discrimination *do* take place in the workplace, and some have suggested that discrimination may be more prevalent and/or

more damaging in careers where women do not have a substantial voice, due to their lack of numbers (Agars, 2004; Benokraitis and Feagin, 1995; J. Steele et al., 2002; Swim et al., 2001). Ironically, at the same diversity conference where Summers diminished the role that discrimination might play in these gender discrepancies, several female scientists described their personal experiences with discrimination, as well as the discrimination that their research had revealed. Despite the fact that gender discrimination in the workplace seems to be decreasing, such experiences are not unique or uncommon; a report released at the Massachusetts Institute of Technology in 1999 indicated that many of the tenured female faculty in the School of Science felt marginalized and that this feeling was accompanied by a gender discrepancy, favoring men, in the allocation of critical resources including salary and research space.

A rich body of research suggests that socialization and discrimination contribute significantly to the observed gender differences in scientific domains, and in recent years emerging research has highlighted the effect that knowledge of self-relevant stereotypes can have on women in mathematics. Despite Summers's 'best guess' that these discrepancies stem primarily from differences in career ambition and natural ability, it is, in reality, the perpetuation of such beliefs that may serve as a powerful, yet sometimes hidden, barrier to women in these domains. In this chapter we focus on the direct and immediate situational effect that gender stereotypes can have on women who are pursuing higher education and careers in the fields of math, science and engineering by reviewing the growing literature on a process termed 'stereotype threat'. Importantly, in the hopes of acknowledging the many women and organizations that have found ways to overcome these hidden barriers, in this chapter we also review research that has identified institutional and personal means of combating the activation of stereotypes and stereotype threat. The majority of this research has been conducted by social psychologists who have examined these processes in controlled laboratory environments (C.M. Steele et al., 2002); however, several studies have recently provided evidence that stereotype threat effects emerge in real-world settings as well (Keller and Dauenheimer, 2003; J. Steele et al., 2002; Stricker, 1998 as cited in Davies and Spencer, 2005).

It is important to note that our focus on gender stereotyping does not diminish the contribution that various other factors, including, but not limited to, discrimination, gender socialization, and work–family concerns make to these gender discrepancies; our goal is simply to recognize and review the now vast literature that demonstrates the power of the situation to influence our behaviors and attitudes.

GENDER STEREOTYPE DEVELOPMENT

In order to be directly affected by the activation of a gender stereotype, a person needs to be aware that a stereotype exists. Stereotypes, or beliefs about the people in our social world, begin to form at a very early age. The majority of children's first stereotypes are based on gender, as this is one of the first social categories that children consistently recognize (Golombok and Fivush, 1994). Between the ages of 3 and 6, children can usually identify a multitude of gender-based stereotypes, and in many cases children also readily endorse them.

It is not completely clear when or how children develop specific gender stereotypes about math and science, but there is reason to suspect that girls are aware of these particular academic stereotypes from early elementary school (J. Steele, 2003; Shih et al., 1999). In some of our own research, girls in early elementary school (grades 1–4) rated men as being better at math and as liking math more than women (J. Steele, 2003). In another study, girls in late elementary school (grades 4–6) displayed a same-sex bias; specifically, girls rated 'most girls' as being better than 'most boys' at both mathematics and reading and writing, and similarly rated women as being better at reading and writing than men. However, when asked to rate the abilities of men and women in mathematics, this pro-female bias disappeared, with girls rating men and women as comparable in this domain. Importantly, when they received an implicit measure of stereotyping, the Implicit Association Test (IAT; Greenwald et al., 1998; Greenwald et al., 2003), both boys and girls in late elementary school showed a strong gender stereotype. Specifically, both groups of children were quicker to associate male pictures with mathematics and female pictures with reading and writing than the reverse pairings (J. Steele et al., 2007). Although these results do not point conclusively to the emergence of a gender stereotype about *mathematics*, they do indicate that from an early age girls begin to differentially associate male and female with specific academic domains at both an explicit and an implicit, or automatic, level.

It is important to note that it is not clear if these stereotypes are reflected in the actual abilities and performance of women in math and science. Although there is evidence that men outperform women on various standardized math tests such as the SAT-M (Gallagher and Kaufman, 2005), some have argued that this difference is often small, and that the distribution of men's and women's scores often has a great deal of overlap (Hyde, 2005). In addition, there is evidence that females and males have strengths in different areas of mathematics; girls and women excel on tests of arithmetic calculation and memory for the spatial location of objects, whereas boys and men tend to excel on tests of mathematical word problems and memory for the

geometric configuration of an environment (Hyde, 2005). A recent review of the literature conducted by Spelke (2005) concluded that girls and boys show equal primary abilities for mathematics and that sex differences only begin to emerge on complex quantitative tasks after elementary school.

Although the evidence regarding differences between men and women on quantitative abilities is somewhat mixed, what *is* clear is that by adolescence and early adulthood, most men and women in North America are aware that a gender stereotype about these domains exists (Crocker et al., 1998). While many actively reject the stereotype, research has now shown that having an awareness of a self-relevant stereotype might be sufficient to diminish performance and reduce one's academic orientation towards stereotyped domains for some women. This can happen through a long-term socialization process and/or through the application of stereotypes by teachers, parents and employers. However, even women who remain very identified with and competent in math and scientific domains are not totally immune to the direct situation-specific effects that stereotypes can have on their performance and identification. It is this situational effect that affects top female students in scientific domains, termed 'stereotype threat', that we review here.

WHAT IS STEREOTYPE THREAT?

In the mid-1990s, Claude Steele and his colleagues, Joshua Aronson and Steven Spencer, put forth a theory of *stereotype threat* (Spencer et al., 1999; C.M. Steele, 1997; C.M. Steele and Aronson, 1995; C.M. Steele et al., 2002). According to this theory, stereotype threat occurs when members of negatively stereotyped groups, such as women in math and science, face the possibility of inadvertently confirming the stereotype about their group. As C.M. Steele and Aronson (1995) explain, '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). According to their theory, the possibility of confirming a negative stereotype can be self-threatening and can lead to a disruptive concern that can interfere with performance in the stereotyped domain. Importantly, this concern is most likely to be evoked among people who care about the domain and find it to be self-relevant; in other words it is women who are talented and identified with math and science who are the most likely to show stereotype threat effects.

Spencer et al. (1999) conducted the first studies designed to test the possibility that women's math test performance could be negatively impacted

by this situational threat. In one study, male and female math-identified students were asked to take a challenging math test under one of two conditions. In one condition, the stereotype threat condition, participants were told that the math test they were about to take had shown gender differences in the past. In the second condition, the no threat condition, participants were told that the test had previously revealed no gender differences. The latter manipulation was designed to make the stereotype irrelevant for women, and therefore eliminate stereotype threat. Consistent with their expectations and with the theory of stereotype threat, women's math test performance was worse than men's when the stereotype was relevant. Importantly, however, these researchers demonstrated that when the test was described as showing no gender differences, women's performance was not depressed relative to men's.

Stereotype threat effects have now been shown to emerge with a host of stereotyped group members including African Americans (C.M. Steele and Aronson, 1995), Latinos (Aronson et al., 1998; Gonzales et al., 2002), and low SES students (Croizet and Claire, 1998) on purported tests of intellectual ability, the elderly on memory tasks (Chasteen et al., 2005; Levy, 1996), and white students on purported tests of natural athletic abilities (Stone et al., 1999; see Wheeler and Petty, 2001 for an additional review). White men have even produced stereotype threat effects on a test of mathematical abilities when they were reminded of a positive stereotype for Asian Americans in this domain (Aronson et al., 1999). However, due to the importance of mathematical skills in the pursuit of higher education, as well as the relative abundance of math-oriented students on university campuses, math-identified women have been one of the most studied groups in stereotype threat studies.

This extensive research on women in mathematics has made it clear that stereotype threat can be induced by a variety of contextual factors. Building on research with various racial groups, stereotype threat effects have now been shown to emerge when a math test is described as being diagnostic of ability (Martens et al., 2006; Marx et al., 2005), as opposed to non-diagnostic of ability. In addition, women's math test performance can be affected by the ratio of men to women in a testing situation (Inzlicht and Ben-Zeev, 2000), social comparison information (Davies et al., 2002; Reisz et al., 2007), and implicitly activated identities (Ambady et al., 2004; Shih et al., 1999).

In one interesting demonstration, Inzlicht and Ben-Zeev (2000) induced stereotype threat by having female participants take a math test in a mixed-sex (with two men), as opposed to a single-sex (with two other women), group. Women who were the only female test taker in their group underperformed on the math test relative to women who were in the room with two other women. These researchers also demonstrated that this effect

occurred only for women's math test performance; women who were asked to take a verbal test instead were unaffected by the gender composition of the room.

In a second study, Inzlicht and Ben-Zeev (2000) showed that the detrimental effect of performing as the minority woman in a stereotyped domain was proportional to the number of males in the group with whom they wrote the math test. Female participants in a mixed-sex majority condition (two women, and one man) experienced more moderate problem-solving deficits than female participants who wrote a math test in a mixed-sex minority condition (two men and one woman). The gender make-up of an environment alone, then, can determine whether gender stereotypes will be activated, and this activation may in turn cause women to experience performance deficits in stereotyped domains such as mathematics.

In our own research, we have found that being presented with information about a male math 'superstar' can similarly depress the performance of math-identified women (Reisz et al., 2007). Previous research has demonstrated that learning about successful others in domains of great importance to us can deflate our feelings of ability, if we believe that we can no longer achieve similar success (Lockwood and Kunda, 1997). Building on these findings, we reasoned that an unattainable social comparison might be particularly threatening if it helps to confirm a negative, self-relevant gender stereotype. We also predicted that such a comparison might not be deflating if it helps to disprove a relevant gender stereotype. To test this possibility, we asked math-identified female undergraduates to read about an extremely gifted first-year math major who was either male (stereotype confirming) or female (stereotype disconfirming). Participants were subsequently asked to take a challenging math test in what they believed to be an unrelated study. In line with our predictions, math-identified women who read about a highly gifted first-year male math student performed more poorly on a subsequent math test than women who read about an identically gifted female math student, or women who read a neutral story.

Stereotype threat can also be induced by simply activating gender stereotypes – even if they are not domain relevant. For example, Davies et al. (2002) found that exposing women to gender-stereotypic television commercials implicitly primed female stereotypes, leading math-identified women to subsequently underperform on a math test (Study 1) and avoid math in favor of verbal items on an aptitude test (Study 2). Further analyses revealed that the level of stereotype activation among the female participants mediated the effect of commercial type on subsequent math test performance, with higher levels of stereotype activation leading to worse performance on the test.

In short, there appear to be multiple, seemingly minor variations to a testing environment that can result in women's underperformance in mathematics. Interestingly, there is reason to believe that similar effects can emerge even when a concern about confirming a negative stereotype is not explicitly induced. In two studies conducted by Ambady et al., activating the social category female through the subliminal presentation of words such as 'girl', 'grandma' and 'skirt' led women to underperform on a challenging math test relative to women who were subliminally presented with neutral words of comparable length (Ambady et al., 2004). Similarly, women in a study by Shih et al. (1999) had decreased math test performance after filling out a one-page questionnaire that subtly reminded them of their gender identity.

Taken together, this research provides strong support for the situational influence that stereotypes can have on women's math test performance. Importantly, the studies demonstrate that stereotype threat can be evoked by a host of situational cues, including test description, gender composition of the room, as well as various subtle and overt factors that make women's gender salient. When considering the effect of stereotypes on women in math and scientific domains, it is important to note, however, that math test performance is not the only potential casualty. Models of achievement-related decisions point to the importance of women's attitudes towards math and science in predicting women's willingness to pursue advanced degrees and careers in these domains (Eccles, 1987; Stangor and Sechrist, 1998), and research has now established that stereotype threatening situations can similarly influence women's identification with these domains.

STEREOTYPE THREAT AND DOMAIN IDENTIFICATION

According to C.M. Steele (1997), to be academically successful a person must *identify* with their field(s) of study in such a way 'that one's self-regard significantly depends on achievement in those domains' (p. 616). Unfortunately, theory and research now support the fact that stereotypes can undermine this identification in several ways. First and foremost, people can simply avoid the domain in which they are stereotyped (C.M. Steele et al., 2002). Women have many occupations and majors available to them, and one of the ways to overcome the risk of being negatively stereotyped is simply to avoid math and science. Clearly there are unfortunate consequences for both the individual and the group when this strategy is adopted; women do not get the opportunity to learn and excel in these

domains, which can limit their long-term career options and ultimately serve to confirm the stereotype. Less drastic, yet similarly detrimental responses include psychological *disengagement* (Crocker et al., 1998) and *disidentification* (C.M. Steele et al., 2002) from the domains. *Disengagement* has been described as a short-term strategy in the face of stereotype threatening situations, whereas *disidentification* is a long-term or chronic response. When feelings of stereotype threat arise, research suggests that women may start to create a psychological distance between the importance that they place on excelling in the domain and their self-concept as a way to protect themselves from future threats to self-esteem (disengagement); this may result in women ultimately leaving these fields of study (disidentification).

At least two studies provide evidence of the situational impact of stereotypes on women's identification. In the previously described research conducted by Davies et al. (2002), women who were exposed to gender-stereotypic television commercials not only underperformed on a math test, but they also reported more interest in majors and careers that involve verbal skills (such as journalism and communications), and significantly less interest in majors and careers that involve quantitative skills (such as engineering and computer science), relative to women who had viewed non-stereotypical commercials. Women who viewed stereotypical commercials also showed a marked preference for verbal over quantitative fields of study that did not emerge for women in a neutral, 'non-threatened' condition.

Additional research has revealed that stereotypes do not need to be explicitly made salient in order to have an effect on women's self-reported interest in quantitative and verbal domains. J. Steele and Ambady (2006) demonstrated that subtle gender primes could shift women's attitudes in stereotype-consistent directions. Women who were subliminally primed with female-related words (Study 1a) or who were reminded of their gender identity through the completion of a one-page questionnaire (Study 1b) subsequently reported a preference for arts-related academic activities (i.e. writing an essay, analyzing a poem) over math-related academic activities (i.e. solving an equation, completing a geometry problem-set), whereas women in control conditions reported an equal interest in both domains.

MEDIATORS OF STEREOTYPE THREAT

If we hope to combat this 'threat in the air', it is important to identify the process through which stereotype threat effects emerge. Early theorizing suggested that anxiety was a key mediator of stereotype threat effects; however, solid evidence based on self-report measures has been inconclusive

(C.M. Steele et al., 2002). Spencer et al. (1999) provided partial support for the role of anxiety in stereotype threat effects. In one study, Spencer et al. found that women who were expecting to take a challenging math test described as showing gender differences reported more anxiety before the test than women who were told the test showed no gender differences. However, the full test for mediation was not statistically reliable, leaving some lingering doubt about the role of anxiety in these effects. In addition, several other studies (see C.M. Steele et al., 2002, for a review) found little or no evidence of increased anxiety among stereotype-threatened participants, despite the fact that the expected performance decrements emerged.

Since those early experiments, there has been new evidence that a variety of mechanisms, and/or some combination of these mechanisms, might result in stereotype threat. Researchers examining stereotype threat effects on women's math test performance have uncovered multiple potential affective and cognitive processes that might mediate these effects, including arousal (Ben-Zeev et al., 2005a; O'Brien and Crandall, 2003), dejection emotions, negative thinking, and a prevention (i.e. wanting to 'not fail') as opposed to a promotion (i.e. wanting to 'succeed') self-regulatory focus (Cadinu et al., 2005; Keller and Dauenheimer, 2003; Seibt and Förster, 2004), reduced working memory capacity (Schmader and Johns, 2003), the attempted suppression of stereotypes (Spencer et al., 2007) and stereotype activation (Ambady et al., 2004; Davies et al., 2002).

While it is beyond the scope of this chapter to describe the details of each of the studies examining these mediational processes (see C.M. Steele et al., 2002 for a partial review), it is important to note that these studies provide some initial indication of strategies for overcoming stereotype threat. Research on the role of arousal provides evidence that stereotype threat effects can be eliminated when women are provided with the opportunity to attribute the source of their arousal to another plausible source (Ben-Zeev et al., 2005b; see also Brown and Josephs, 1999, who made use of a self-handicapping misattribution paradigm to alleviate stereotype threat). In addition, research examining thought suppression (Wegner, 1994) in conjunction with the findings of Spencer et al. (2007) suggests that women in stereotype-threatening situations might overcome repeated attempts to suppress stereotype activation by substituting another thought. In one study, stereotype-threatened women showed improved performance when they were told to think about a valued identity each time a stereotype-related thought came to mind during a challenging math test (Spencer et al., 2007).

Finding ways of overcoming stereotype threat has not been the goal of most researchers examining mediational processes, and yet this work provides initial suggestions for how to allay threatening environments.

Building on these and other findings, some researchers have begun to specifically examine whether short-term or long-term interventions and strategies can be introduced to help counteract these situational threats. In an attempt to better understand this phenomenon, researchers have also begun to identify individual differences in people's tendency to be affected by the possibility that they might confirm a negative stereotype about their groups. The findings of these studies are reviewed below.

OVERCOMING STEREOTYPE THREAT

At first glance, it would seem that one of the best ways to overcome feelings of threat associated with being stereotyped is to become extremely skilled in the domain. Spencer et al. (1999, Study 1; see also O'Brien and Crandall, 2003) demonstrated that stereotype threat effects only emerge when math-identified women are presented with a *challenging* test of their mathematical abilities; in their research, such gender differences did not emerge when men and women were presented with an easier test of mathematical prowess. As test difficulty is dependent on skill level, women who are exceptionally skilled may face less concern about inadvertently confirming a negative stereotype about their group, simply because these women might not be as challenged by situations in which higher math abilities are expected.

This route to overcoming stereotype threat is a tenuous one, however, as any person striving to be successful in higher education should ultimately face challenges, no matter what their skill level. And as C.M. Steele (1997, p. 618) explains,

> For the advanced female math student who has been brilliant up to that point, any frustration she has at the frontier of her skills could confirm the gender-based limitation alleged in the stereotype, making this frontier, because she is so invested in it, a more threatening place than it is for the nonstereotyped. Thus, the work of dispelling stereotype threat through performance probably increases with the difficulty of work in the domain, and whatever exemption is gained has to be rewon at the next new proving ground.

Even a very talented female scientist would need to disprove the stereotype by re-establishing her skills and ability in each new context that she encountered; if she faltered, even slightly, she would again risk being viewed as representative of her gender group, instead of as an individual.

At a societal level, another obvious way to overcome stereotype threat would be to dispel the stereotype entirely. This, again, is difficult given the staggering statistics about women's underrepresentation in these domains.

Although these statistics alone hardly provide concrete evidence that women are not as skilled at, interested in, or dedicated to these domains as men, they do provide solid evidence of a gender difference. As more women enter these educational domains, it is likely that this stereotype will be dispelled; in the meantime this strategy alone is not a viable possibility.

Given the inherent limitations to these approaches, researchers have theorized and demonstrated more viable routes to help combat the threat that stereotypes can impose. Stereotype threat is a *situation*-specific phenomenon and accordingly some theory and research has focused on ways to alter educational environments to reduce the possibility that stereotyped group members feel concern that they will be viewed through a stereotyped lens (McIntyre et al., 2003; C.M. Steele, 1997; C.M. Steele et al., 2002). In addition, recent research has demonstrated that specific *personal interventions* can be used to help eliminate the effect that stereotypes can have on women's math test performance (Ambady et al., 2004; Croizet et al., 2001; Martens et al., 2006; Shih et al., 1999). Finally, a third line of research has sought to determine *individual differences in susceptibility and responses to stereotype threat* (Pronin et al., 2004; Schmader, 2002; Schmader et al., 2004; J. Steele, 2003; J. Steele et al., 2007). Research based on each of these three paths is described in greater detail below.

SITUATIONAL INTERVENTIONS

According to C.M. Steele (1997), there are situational changes that can be put in place in educational and occupational settings to reduce the probability that women will feel concern about being viewed stereotypically. Steele specifically outlines three 'wise schooling' strategies that can help women who are both domain identified and non-identified. The first strategy of wise schooling is to build optimistic teacher–student relationships. Stereotypes can lead women to feel concerned that their teachers or employers will question their abilities; accordingly it is vital that this possibility be explicitly disavowed in any mentoring context. Additional strategies include emphasizing challenge over remediation when there is a need for skill building and focusing on the malleability of intelligence through experience and training. Previous research has found that negative feedback provided to boys often focuses on their poor behavior or lack of effort, whereas negative feedback given to girls often emphasizes intellectual shortcomings (Dweck et al., 1978). These different types of feedback implicitly convey the view that boys have the potential to succeed with sufficient effort whereas girls are inherently limited. By focusing on the

expandability of human intelligence in stereotype-threatening contexts, girls and women will have a greater potential to thrive.

For women who are already invested in the domain of mathematics, there are additional institutional interventions that can help to reduce the probability that they will disidentify with the domain. First, it is important to 'affirm domain belongingness' by explicitly reinforcing that women are welcome and accepted in mathematical and scientific contexts. Clearly this needs to be done appropriately, to ensure that this affirmation does not inadvertently serve to activate stereotypes. Second, it is important to value multiple perspectives in the classroom or work environment. Finally, C.M. Steele (1997) suggests that it is critical to provide women with positive role models. Female mathematicians who have been able to flourish despite their membership in a negatively stereotyped group carry with them the encouraging message that these obstacles can be overcome.

To date the majority of research that has been conducted on 'wise schooling' practices has focused on racial minority group members as opposed to women in math and science (C.M. Steele et al., 2002). However, there is no reason to believe that similar strategies and interventions would not be equally successful with women in mathematics. And there is some laboratory-based research to support this possibility. For example, several studies have demonstrated that providing information about a successful role model can effectively combat stereotype threat effects (Marx and Roman, 2002; Marx et al., 2005; McIntyre et al., 2003). In one study, researchers buffered threat-induced performance deficits in undergraduate women by explicitly portraying the female experimenter as highly competent in mathematics. In contrast, portraying the female experimenter as having a low level of competence in math resulted in poorer math test performance (Marx and Roman, 2002, Study 2). In other research, reminding participants of other domains in which women have succeeded alleviated the effects of stereotype threat on a subsequent math test (McIntyre et al., 2003). These findings provide some laboratory-based support for the importance of positive role models in reducing the debilitating effects that stereotype threat can have on women's math performance.

In short, theorizing and research suggest that there are ways that educational institutions and organizations can combat stereotype threat. Importantly, these contextual interventions can work in conjunction with policies designed to foster work–family balance and combat group-based discrimination. However, individuals who find themselves in stereotype-threatening situations are not often in a position to change their environments; accordingly, it is important to acknowledge interventions that can be implemented at an individual level that help to combat stereotype threat effects.

PERSONAL INTERVENTIONS

Researchers have examined the use of *self-affirmation* as a way for an individual to combat stereotype threat (Croizet et al., 2001; Martens et al., 2006). According to the theory of self-affirmation, one of our primary social motivations as individuals is self-integrity maintenance. Early self-affirmation research has demonstrated that when people are faced with a threat to their self-integrity (i.e. after receiving negative feedback), they will look to affirm themselves as a way of dealing with or overcoming this threat (C.M. Steele et al., 1993; Fein and Spencer, 1997). If stereotype threat presents a threat to self-integrity for people who are highly identified with a given domain, then affirming their identity by recruiting other positive aspects of the self should alleviate that threat.

To test this possibility Martens et al. (2006, Study 1) asked math-identified women to take a math test under stereotype-threatening or non-stereotype-threatening conditions. They then provided half of the stereotype-threatened women with the opportunity to affirm themselves prior to taking the test, by asking them to write about an important personal value. As expected, stereotype-threatened women who affirmed an important part of their identity subsequently performed as well as non-stereotype-threatened women, and significantly better than threatened women who did not self-affirm on a challenging test of their mathematical abilities. Similar results emerged in another study by Croizet et al. (2001) in which women's student identity was affirmed in a stereotype-threatening situation. Stereotype-threatened women who were led to believe that they were more intellectually curious and helpful than other students (a self-affirmation manipulation) just before completing a challenging math test performed as well as women in a non-stereotype-threatened condition. Such results suggest that one way to alleviate stereotype threat is to affirm the self by recruiting information central to the person's being, such as a key value or characteristic. As Croizet et al. note, to be effective, this information needs to be 'at least as important to the individual's perception of self-adequacy as are the negative images inherent in the threat' (C.M. Steele, 1988, p. 291).

In our own work, we have found *individuation* to be another means of combating the effects of stereotype activation on women's math test performance (Ambady et al., 2004). After being primed with the concept 'female' or with neutral words, undergraduate women were given a questionnaire designed to either provide them with the opportunity to think about their uniqueness (the individuation manipulation) or designed to serve as a filler task (control condition) before taking a challenging math test. We hypothesized that women who thought about their uniqueness would gain some distance from group-based stereotypes, thus rendering the

negative stereotype about women's inferior math ability irrelevant in the testing situation. As expected, women in the individuation condition performed better than gender-primed women who were not individuated, and performed as well as women who were not gender-primed.

It is important to note that in each of these studies, participants were unaware of the intended results of the experimental manipulations. It therefore remains unclear whether women in a scientific occupation or major could combat stereotype threat by generating self-affirming or individuating thoughts in situations where they realize that they might be affected by stereotype threat. This research similarly does not determine whether women who succeed in math and scientific domains already make use of these strategies. Nonetheless, these results provide some initial indication that individual-based interventions can be introduced to combat the effects of stereotype threat.

Another way that women might overcome stereotypes is through the activation of other group identities that are not negatively stereotyped. The self-concept is composed of a diversity of social identities and each of these identities may have different, even opposing, stereotypes associated with them (Shih et al., 1999). For example, a woman majoring in mathematics may also be a soccer player, a musician, a practicing Catholic, and an Asian American. Not all of these identities will be salient at a particular moment in time, however; the working self-concept is believed to be those aspects of our identities that are salient to us at a given moment (Markus and Wurf, 1987). When taking a math test that has been described as previously showing gender differences, a woman's gender identity becomes salient, which induces concerns related to confirming a negative math stereotype. However, subtly reminding this woman of her positively stereotyped Asian identity might help to combat these effects.

To test this possibility, Shih et al. (1999) recruited Asian-American women and asked them to complete a one-page questionnaire followed by a challenging math test. The questionnaire included items that were designed to subtly remind women of either their positively stereotyped racial identity (i.e. 'Do your parents or grandparents speak any languages other than English?'), their negatively stereotyped female identity (i.e. 'Do you prefer co-ed or single-sex dormitories?'), or in a control condition, no particular identity (i.e. 'Would you consider subscribing to cable television?'). Consistent with societal stereotypes, participants in the Asian-prime condition performed significantly better on the math test than women in the female-prime condition, relative to participants in the control condition. These results are particularly intriguing as no direct mention of the stereotypes themselves was ever made; Asian-American women were only reminded of aspects of their *identities*. However, caution would need

to be used in adopting this as a strategy to combat stereotype threat. Subsequent research has shown that if people are made blatantly aware of their positively stereotyped identities, their performance can actually be impaired, likely due to a concern about whether they will be able to live up to the stereotype (Cheryan and Bodenhausen, 2000; Shih et al., 2002).

One final, albeit less practical, strategy that we have examined in our research involves having participants physically approach mathematics (Kawakami et al., 2007). Social psychological research on approach–avoidance behaviors has demonstrated a general facilitation for approaching liked objects and avoiding disliked objects (Chen and Bargh, 1999; Solarz, 1960). Importantly, this body of research has also shown that for neutral attitude objects as well as social categories, people can develop a greater liking for items that they approach as opposed to avoid (Cacioppo et al., 1993; Förster and Strack, 1997; Kawakami et al., in press; Priester et al., 1996). Building on this literature, we examined whether training women to approach math-related objects would result in a more positive attitude and orientation towards this domain.

Unlike the majority of stereotype threat research, we recruited women who were not particularly identified with mathematics. Non-identified women in an experimental condition received extensive practice in approaching math-related pictures on a computer screen by pulling a joystick towards themselves, whereas women in a control condition were asked instead to move the joystick to the side (right or left). In line with our predictions, women who were trained to approach math-related objects were subsequently quicker to associate math with self-related words on an implicit measure of math identification. In addition, they attempted more questions on a challenging math test than women in a control condition. These findings suggest that one way to increase women's participation in domains such as mathematics may simply be to encourage women to approach these domains. In this study, 'approach' involved a very basic-level process (a simple, repeated arm movement); however, these findings suggest the possibility that a variety of approach behaviors such as female-friendly teaching formats and classroom environments that challenge avoidance orientation and draw otherwise unidentified women in, could have a profound impact on women's orientation towards this domain.

INDIVIDUAL DIFFERENCES IN SUSCEPTIBILITY AND RESPONSES TO STEREOTYPE THREAT

In addition to identifying situational and personal interventions aimed at combating stereotype threat, researchers have also attempted to identify

individual differences that might moderate women's susceptibility to stereotype threat effects in mathematics, as well as long-term strategies that women in these domains adopt. It is important to reiterate that one set of strategies aimed at dealing with the risk of confirming a negative stereotype is simply to avoid, disengage or disidentify with the stereotyped domain. These strategies no doubt contribute to the current underrepresentation of women in math, science and engineering; however, it is clearly not the ideal strategy if we wish to increase the number of women in these fields. Of greater interest are those individual differences and strategies that allow women to remain engaged with these fields of study.

Schmader and her colleagues have found that women's identification with their gender group, as well as their willingness to endorse gender stereotypes, moderate stereotype threat effects (Schmader, 2002; Schmader et al., 2004). In one study, Schmader (2002) asked women and men to take a challenging math test under one of two conditions: participants in the stereotype threat condition were told by a male experimenter that the researchers were interested in women's performance relative to men, whereas participants in the control condition were told that the researchers were interested in the individual performance of women and men. Schmader then used previously collected information about participants' gender identification to examine whether stereotype threat effects would be more pronounced for women who were highly identified with their gender group. In line with her predictions, Schmader found that women high in identification with their gender group, as indicated by their agreement with statements such as 'Being a woman is an important reflection of who I am' (Luhtanen and Crocker, 1992), were more susceptible to this stereotype threat manipulation than women who reported a low level of gender identification. Although not conclusive given the experimental design, these findings suggest that one way women might overcome the threat that gender stereotypes can impose is to simply reduce the extent to which their gender identity is central to their self-concept.

In line with these data, Pronin et al. (2004) investigated the possibility that female math majors selectively reject only those aspects of femininity that might be perceived as hindering their ability to succeed in mathematics, a process they have termed *identity bifurcation*. In one study, Pronin et al. (Study 1) asked women enrolled in undergraduate math classes to rate the extent to which various characteristics applied to them and were important to their sense of self. These items included characteristics that were pre-tested to be feminine and stereotypically associated with a lack of potential in mathematics (i.e. emotional, flirtatious, family-oriented), feminine and not associated with a lack of math potential (i.e. sensitive, nurturing, fashionable), and masculine (i.e. competitive,

aggressive, analytical). Consistent with their predictions, women who had previously taken a large number of courses in mathematics only rated the traits that were feminine and stereotypically associated with a lack of potential in mathematics (and not the traits that were feminine and not associated with a lack of math potential or masculine traits) as less representative of themselves than women with less exposure to courses in mathematics. These findings suggest that one way some women might overcome stereotype threat is by rejecting, at least temporarily, certain aspects of femininity (such as wearing make-up or flirting).

Finally, we have suggested that a related process, termed *stereotype stratification*, might emerge among targets of negative stereotypes (J. Steele, 2003; J. Steele et al., 2007). The term *stereotype stratification* is used to refer to the process of 'cognitively viewing oneself as a member of a subgroup to which the stereotype does not apply' (J. Steele, 2003, p. 2590). For example, girls might develop a gender stereotype that is specific to women (an age subgroup to which they do not currently belong), whereas boys might develop a global gender stereotype about mathematics. In an initial demonstration of this possibility, girls in early elementary school were asked to rate how good they found boys, girls, men and women to be at mathematics. Consistent with this theory, girls rated boys and girls as having comparable abilities, but rated men being better at math than women (J. Steele, 2003). In a subsequent study, boys and girls were asked to draw a picture of a gender-unspecified mathematician who was described as being either an adult or a child. Again consistent with our expectations, boys drew a male mathematician regardless of whether they were asked to draw a child or an adult. By contrast, the gender of girls' drawings depended on the age of the mathematician described; girls were more likely to draw a child mathematician who was female and an adult mathematician who was male (J. Steele, 2003). These findings suggest that girls might be redefining this stereotype in a way that is temporarily self-protective.

Although it is unclear whether these individual and group differences reflect protective strategies that have been adopted, it should be noted that there are potential costs associated with adopting any of these strategies in an attempt to overcome stereotype threat. Women who distance themselves from their gender group, or from specific aspects of their gender identity, might lose the psychological protection that group membership can often afford. Alternatively, by redefining the stereotype in the short term, girls might find themselves more susceptible to stereotype-threatening situations as they move into womanhood. In addition, each of these strategies might increase women's likelihood to stereotype other women who have not adopted a similar approach. Nonetheless, these data provide some

interesting insight into the ways that successful female mathematicians and scientists might deal with stereotype-threatening situations.

CONCLUSION

This chapter began with a seemingly straightforward question: Why are there fewer women than men pursuing and succeeding in prestigious careers in math and scientific domains? The goal of this chapter was not to review the multitude of potential factors that contribute to this gender discrepancy; instead, we set out to review the growing literature examining the situational impact of gender stereotypes on women's math test performance and their identification with this domain. What is clear from this literature is that gender stereotypes can have an immediate and consequential effect on women's performance and identification with the field of mathematics. Importantly, this literature also suggests that there are strategies that can be adopted by institutions and individuals to help combat this situational threat. Although this literature provides some insight into our initial question, future research is needed to determine the conditions under which stereotype threat emerges in naturalistic settings, and importantly, to better understand how successful women in these fields have been able to surmount these potential obstacles.

One final question to emerge from this literature is whether it is beneficial or detrimental for women in the sciences to learn about stereotype threat. There is research to suggest that knowledge in this case is beneficial. Johns et al. (2005) found that women in an experimental condition who received a 'teaching intervention' designed to educate them about stereotype threat performed better than other women in a math testing situation. In addition, the more the women in the experimental condition attributed any anxiety they felt to gender stereotypes, the better they performed. This was in contrast to women who took the test without first learning about stereotype threat; the more the women in this control group made attributions to gender stereotypes, the *worse* they performed. In short, this research provides some indication that educating women might provide one strategy to reduce the situational impact of stereotypes on women in mathematics.

Although women continue to be underrepresented in math and scientific domains, there is great hope for the future. Women have made steady progress in their representation in these domains, and these numbers will undoubtedly continue to climb. As more women enter these fields, stereotypes will likely cease to be a hidden barrier to be confronted. And through continued research aimed at understanding stereotype threat, we will, we hope, have more information to share on how this current obstacle can best be overcome.

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NOTE

1. In a critical review of the scientific data on sex differences in cognitive abilities, renowned developmental psychologist Elizabeth Spelke (2005, p. 956) concluded that 'research on the cognitive abilities of males and females from birth to maturity does not support the claim that men have a greater intrinsic aptitude for mathematics and science'.

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