Implicit social cognitions predict sex differences in math engagement and achievement

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Abstract

Gender stereotypes about math and science do not need to be endorsed, or even available to conscious introspection, to contribute to the sex gap in engagement and achievement in science, technology, engineering and mathematics (STEM). We examined implicit math attitudes and stereotypes among a heterogeneous sample of 5,139 participants. Women showed stronger implicit negativity toward math than men did, and equally strong implicit gender stereotypes. For women, stronger implicit math=male stereotypes predicted greater negativity toward math, less participation, weaker self-ascribed ability, and worse math achievement; for men, those relations were weakly in the opposite direction. Implicit stereotypes had greater predictive validity than explicit stereotypes. Female STEM majors, especially those with a graduate degree, held weaker implicit math=male stereotypes and more positive implicit math attitudes than other women. Implicit measures will be a valuable tool for education research and help account for unexplained variation in the STEM sex gap.

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The mere fact that women are less likely than men to pursue and persist in many science, technology, engineering, and math (STEM) college majors and careers is widely recognized; but why the sex gap occurs is the focus of intense ongoing study. Halpern and colleagues (Halpern et al., 2007) reviewed decades of evidence and concluded that the problem is complex—"no single or simple answers"—but acknowledged a scholarly consensus that the contribution of stereotyping and discrimination now derives partly from cognitive processes that function outside of awareness. A panel of experts commissioned by the National Academies of Science (2007) further emphasized the presumed role of unconscious bias in perpetuating the gender gap in STEM: "Decades of cognitive psychology research reveals that most of us carry prejudices of which we are unaware but that nonetheless play a large role in our evaluations of people and their work." (Executive Summary, p. 3).

Unconscious bias, or implicit social cognition, might affect the STEM sex gap in two ways, by (1) causing STEM gatekeepers and influential adults (e.g., teachers, administrators, parents) to, unintentionally, behave differently toward females than toward males in STEM-related contexts; and by (2) undermining girls' and women's interest, feeling of belonging, willingness to persist and actual achievement in math and science-related activities. This article focuses on the latter possibility and reports evidence that implicit math cognitions predict variation in math engagement and achievement, especially for women, that is not accounted for by self-reported thoughts, feelings, and beliefs about math. Math is a particularly important skill for scientific practice; engagement with math can be seen as a gateway to engagement with science more generally. The results reported here suggest that education theory and research will benefit by further incorporating implicit measurement for understanding academic engagement and achievement.

Implicit Social Cognition

Theory and evidence accumulating during the last two decades suggests that social evaluation can be distinguished as two types: one that is explicit, characterized by intention, awareness, and control, and one that is implicit, characterized by lack of intention, awareness, or control (Bargh, 1994; Gawronski & Bodenhausen, 2006; Greenwald & Banaji, 1995; Strack & Deutsch, 2004). Because implicit, or automatic, processing can occur without awareness or control, behavior may be influenced by thoughts that are unrelated to, or even directly contradict explicit, endorsed beliefs or values.

The methods of implicit social cognition are quite distinct from the explicit, self-reported methods of measuring attitudes, identities, and stereotypes. Asking a person "How much do you like science?" or "Do you believe that math is more for men than for women?" requires a self-assessment – an introspection of one's thoughts and feelings and the translation of that assessment into a response. Explicit measures draw on mental information that is accessible to the respondent, and the respondent can control what is communicated. Such expressions are valuable indicators of respondent's explicit beliefs. However, conscious experience captures only a small portion of mental processing (Nisbett & Wilson, 1977; Nosek, 2007; Wilson, 2002). Significant portions of the mind are not easily accessed by introspective efforts, and what is accessible might be altered for personal or social purposes. A woman, for example, might have a thought come to mind that science is for men, but not report it because she does not want others to know she believes that, or because she honestly does not believe it even though it came to mind. Moreover, the origins of a person's behavior lie not only in their intentions and self-understanding, but also in the automatic processes of the mind that may elude awareness or control.

Implicit measures, such as the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) are designed to assess mental processes that the respondent may be unwilling or unable to report (Greenwald & Banaji, 1995). The IAT is presently the most popular implicit measure with more than 700 empirical applications in print, and it assesses the strength of association between concepts (for reviews of its psychometric properties, accumulated validity evidence, and methodological strengths and limitations, see De Houwer et al., 2009; Greenwald et al., 2009; Lane et al., 2007; Nosek, Greenwald, & Banaji, 2007). Among implicit measures, the IAT is the most heavily used, in part, because of its flexibility for a variety of applications, ability to elicit large effects, sensitivity to individual differences, and relatively good internal consistency compared to other implicit measures.[1]

The IAT is a behavioral task in which respondents categorize words or images into groups as quickly as possible (try it at: https://implicit.harvard.edu/). The IAT has two critical conditions in which items representing four concepts – e.g., science (physics, chemistry), humanities (arts, language), male (him, man), female (her, woman) for a measure of academic gender stereotyping – are categorized one at a time using two computer keys. In one condition, items representing *science* and *male* are categorized with one key, and items representing *humanities* and *female* are categorized with the other key. In a second condition, items representing *science* and *female* are categorized with one key, and items representing *humanities* and *male* are categorized with the other key (in practice the order of the two conditions is randomized between subjects). The logic of the task is that categorization will be faster if the items sharing a response key are associated in memory than if the items are not associated. For example, participants who are able to complete the categorization task more quickly when *male* and *science* are categorized together compared to when *female* and *science* are categorized together are said to have an implicit stereotype associating male more with science. Such associations may exist despite a respondent's intent *not* to express them, and perhaps even without awareness that those associations are present in memory. As such, many participants who consciously express having no gender stereotype about science may nonetheless show evidence of possessing an implicit stereotype (Nosek, Smyth, et al., 2007).

The IAT is just one of a variety of measures of implicit social cognition. Alternatives include the Affective Misattribution Procedure (AMP; Payne et al., 2005), evaluative priming (Fazio et al., 1986), Go/No-go Association Task (GNAT; Nosek & Banaji, 2001), the Sorting Paired Features task (SPF; Bar-Anan, Nosek, & Vianello, 2009), and variants of these. Each procedure has a unique set of methodological idiosyncrasies that make it more or less relevant for particular research applications (see Gawronski & Payne, 2010 for discussion of a variety of measures and their applications).

Based on the accumulated evidence with the IAT, implicit cognitions are related to, but distinct from explicit cognitions (Nosek & Smyth, 2007), and multiple factors moderate their relationship such as self-presentation concerns, evaluative strength, and perceived distinctiveness of one's own evaluations compared to others (Nosek, 2005).

Implicit cognitions predict behavior – even accounting for variation in behavior that is not explained by explicit cognitions (see meta-analysis by Greenwald, Poehlman, Uhlmann, & Banaji, 2009). Implicit and explicit cognitions apparently form via distinct mechanisms, with implicit cognitions appearing to be sensitive to exposure to associations between concepts whether one agrees with them or not (Gregg, Seibt, & Banaji, 2006; Ranganath & Nosek, 2008; Rydell & McConnell, 2006). Finally, implicit cognitions are sensitive to interventions for long-term change, such as the effect of cognitive-behavioral treatment for spider phobia on reducing implicit spider=afraid or spider=danger associations (Teachman & Woody, 2003) and also to the immediate social context, such as temporarily strengthening female=strong associations by first thinking about female leaders (Blair, Ma, & Lenton, 2001), or shifting implicit attitudes toward Black females by subtly shifting the context to emphasize their race or gender (Mitchell, Nosek, & Banaji, 2003). There is a rich literature focused on the processes that contribute to implicit evaluation and it is shaping our understanding of how implicit processes influence judgment and behavior (for reviews and relevant discussion see De Houwer et al., 2009; Gawronski & Payne, 2010; Nosek, Hawkins, & Frazier, 2011).

Despite the now sizable scientific literature using implicit measurement that started in psychology and extended to applications in health, medicine, law, and business, implicit measures have not been frequently applied in education research.[2] The relative lack of application of implicit measures is notable considering that the theoretical importance of implicit social cognition in education, generally, and in STEM particularly, has been highlighted in the education literature and beyond, such as the comments from the National Academy of Sciences report (2007) in the opening of this article. Another goal of this report, therefore, is to illustrate the value of including implicit measurement in education research, particularly for understanding STEM engagement, so that empirical evidence of the meaningful effects of implicit mindsets can employed to evaluate the recent theorizing about their relevance.

Evidence for implicit stereotypes and attitudes about gender and STEM

A sizable body of evidence shows that implicit stereotypes about math and science are widespread and related to important indicators of math and science engagement and achievement. A sample of 299,298 respondents showed a strong tendency to associate male with science and female with humanities more than the reverse on the IAT (Nosek, Smyth, et al., 2007). The average effect size across respondents was $d = .93$, and implicit stereotypes were positively but modestly related to explicit stereotypes, $r = .22$. Further, implicit stereotyping was similarly strong between men and women, and across races/ethnicities. The only notable demographic group differences were that implicit gender-science stereotypes were stronger among older participants (e.g., $d = 1.30$ among respondents over 60) than younger ones (e.g., $d = .88$ among respondents under 20) suggestive of developmental or generational changes (the data were cross-sectional, preventing discrimination between these possibilities).

In a related investigation, Nosek, Smyth, et al. (2009) calculated national estimates of implicit gender-science stereotyping for 34 countries and correlated these with standardized indicators of countries' sex differences in 8th-grade science and math achievement from the TIMSS project (Gonzales et al., 2004). Nations with stronger average implicit science=male stereotypes had larger sex differences favoring boys in science and math achievement. Similar relations between implicit stereotypes and actual achievement have also been observed among college undergraduates (Kiefer & Sekaquaptewa, 2007a; Nosek, Banaji, & Greenwald, 2002).

Cognitive consistency theories and their application to STEM-related identities and stereotypes

In parallel with the rise of implicit measures, theoretical innovations have developed that anticipate the structure and function of implicit cognitions and their relationship with behavior. Cognitive consistency plays a central role in a variety of classic psychological theories concerning the organization of mental associations (Abelson et al., 1968; Festinger, 1957; Heider, 1958; Osgood & Tannenbaum, 1955). Greenwald and colleagues (Greenwald et al., 2002) revived cognitive consistency principles with application to relations among implicit social cognitions – self-concepts, attitudes, and stereotypes. The core theoretical principle of cognitive consistency is this: if two concepts (A and B) are associated, then they will tend to share the same association with a third concept (C). For example, if math (concept A) is associated with male (concept B), then they should have the same relationship with the self (concept C). If male is associated with the self (as should be true for most men), then cognitive consistency suggests that the self will also be associated with math. However, if male is not associated with the self (as should be true for most women), then cognitive consistency suggests that the self will also not be associated with math. In short, a person's identification with math will be a function of math's relation with gender (stereotype) and gender's relationship with the self. As this example suggests, self-concepts are central elements of the theory – one's own identification with a topic, and subsequent interest and engagement, is a function of the associations of that topic with one's social identities and stereotypes about those identities.

Greenwald and colleagues (2002) found that implicit cognitions conformed to cognitive consistency principles even when self-reported identities and stereotypes did not. For example, a person may recognize that men are more strongly associated with math, but consciously reject it as a basis of deciding his or her own identification with math. Implicitly, however, the mere fact of an association between male and math may make it easier for men and harder for women to associate themselves with mathematics. And, critically, implicit disidentification with math among girls and women may lead them to be less engaged with math – perhaps without even recognizing that the stereotype is playing a role.

Nosek, Banaji, and Greenwald (2002) found initial evidence of cognitive consistency in implicit math attitudes, stereotype, and identity in samples of Yale undergraduates. They investigated implicit gender-math stereotypes as well as implicit attitudes (associations of math and arts with the concepts good and bad), implicit identity (associations of math and arts with the concepts self and others), and implicit gender identity (associations of male and female with self and other). Following cognitive consistency predictions: (1) implicit attitudes toward math were positively related with implicit identification with math; (2) stronger implicit stereotyping of math as male was associated with more negative attitudes toward and less identification with math for women but weakly in the opposite directions for men; and (3) stronger associations of self with female was related to weaker associations of self with mathematics. In short, women who implicitly associated math with male were less likely to identify with math, especially if they were strongly identified with being female.

These relationships suggest that implicit stereotypes, even when they are held by women who explicitly reject the stereotype, could predict their interest and identification with math and science. By implication, women who do not show the implicit stereotype – either because they have been exposed to counter-stereotypic information or have developed other strategies for maintaining a link between self and math – may be more likely to pursue and persist in math and science than women who hold a strong implicit stereotype, regardless of their explicit beliefs. In this article, we aimed to extend this line of theory and evidence to clarify the role of implicit cognitions in understanding the sex gap in engagement with math and science.

This study includes four IATs measuring associations about math. Table 1 presents an overview of the measures. Three of them are related in assessing different aspects of favorability toward math – attitudes, identity, and anxiety. *Attitude* refers to the extent to which math is associated with the concept *good* compared to the concept *bad* (Greenwald et al., 1998). *Identity* refers to the extent to which math is associated with the concept *self* compared to the concept *other* (Greenwald et al., 2002; Nosek et al., 2002). And, *anxiety* refers to the extent to which math is associated with the concept *anxious* compared to the concept *confident*. In each case, stronger associations with good, self, and confident are presumed to be indicative of a more favorable orientation toward mathematics. And, in fact, while attitudes, identity, and anxiety are distinct constructs, the results in the present article show that they are strongly correlated. For simplicity of reporting, therefore, they are presented in the aggregate as an index of implicit *favorability* toward math.

The fourth IAT measured *stereotype* associations – how much is math associated with *male* compared to *female* (Nosek et al. 2002). Like favorability toward math, a wide variety of theories suggest that stereotypes play an important role in accounting for the sex gap in STEM.

Theory and evidence that stereotypes predict STEM engagement and achievement

Social stereotypes figure prominently in many theories of engagement and achievement in math and science (Aronson & Steele, 2005; Eagly & Steffen, 1984; Eccles, 1987; Fennema, 1985; Hackett & Betz, 1981; Jacobs, 1991; Leder, 1986; Parsons, 1983, 1984; Steele, 1997; Wigfield & Eccles, 2002; Wigfield & Wagner, 2005). Most of these models are amenable to, or even anticipate, a role for implicit stereotyping beyond what might be explained by explicit stereotypes. While Marsh and Yeung (1998) concluded that stereotypes and differential socialization exerted little influence on the development of adolescents' academic self-concepts from eighth grade on, recent work by Cvencek, Meltzoff and Greenwald (2010) suggests that the math-is-male stereotype, evident implicitly and explicitly by early elementary school, may have exerted a potent influence on self-concepts prior to adolescence. Specifically, Cvencek and colleagues found that boys and girls as early as second grade evidenced explicit and implicit math-is-male stereotypes, and also that the young boys already held stronger explicit and implicit math self-concepts than did the girls. Cvencek et al. argue that a causal developmental sequence of stereotypes differentially influencing boys' and girls' academic identities is more consistent with their data than the reverse direction and fits with the theory and evidence accumulated by Eccles and her colleagues (Eccles, Wigfield, Harold, & Blumenfeld, 1993).

Our goal was to examine whether implicit stereotypes, particularly, were associated with a range of traditional indicators of adult math engagement and may bear on understanding women's persistent underrepresentation among certain sub-disciplines and at the highest levels of STEM accomplishment in a way that explicit measures do not. As explicit stereotyping has become increasingly discouraged, we suspect that the role of implicit stereotyping in shaping what seem to be conscious decisions about math engagement may be greater now than ever before. We hypothesize that variation in the implicit math-is-male stereotype among members of our diverse adult sample will account for variance in a wide array of well-known and frequently-used indicators of math engagement—math attitude, self-concept/identification, anxiety, participation, self-ascribed ability, achievements on high stakes tests, and choice of STEM major (e.g., Aiken, 1961, 1963; Betz & Hackett, 1981; Chipman, Krantz & Silver, 1992; Ethington, 1991; Fennema & Sherman, 1976; Hackett & Betz, 1983; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Smith & White, 2001)—beyond that accounted for by self-reports of gender-stereotypic associations. These indicators of math engagement each have long histories in theory and empirical research. Many models anticipate that attitudes and stereotypes will predict STEM engagement and achievement. Our investigation is not intended to parse among the important nuances differentiating each theory, but rather to demonstrate an effect that all would be prepared to accommodate. If implicit measures can contribute uniquely to predicting variation in STEM outcomes, it would suggest new avenues for theoretical and empirical investigation in understanding the sex gap in STEM engagement.

Study Overview

Our study was designed with a number of objectives:

1. Replicate and extend the observation of sex differences in implicit math attitudes and identity from Nosek and colleagues (2002) to implicit math anxiety and to a large sample with wide diversity in age and education. In particular, we anticipated that women would show less implicit favorability (less positive attitude, weaker association with self, more anxiety) toward math than men would, and that both men and women would implicitly associate math with male more than with female.
2. Investigate cognitive consistency in the interrelations among implicit math and gender identities, attitudes, and stereotypes, hypothesizing different patterns for males and females. According to consistency principles, implicit stereotyping of math as male would be associated with more favorability toward math among men and less favorability toward math among women.
3. Examine the implicit math cognitions of males and females in the vanguard of math engagement – those that pursued or are pursuing STEM-related undergraduate and graduate degrees. Women in STEM have a social identity that conflicts with the cultural stereotype. How do they resolve the incongruity? Despite being heavily exposed to gender stereotypes about math and science, we anticipated that women in STEM would show greater implicit favorability toward math and weaker implicit stereotyping of math as male

than men and women in non-STEM fields. This could occur because (a) women with greater implicit math favorability and weaker implicit gender stereotypes are more likely to select STEM fields, or (b) the psychological act of selecting STEM as an academic identity shifts implicit attitudes and stereotypes in the direction of cognitively consistency with that identity.

4. Investigate the convergent and predictive validity of implicit cognitions on important indicators of math engagement. Implicit social cognition theory and evidence suggests that implicit attitudes and stereotypes have implications for decision-making and behavior (Greenwald et al., 2009). We examined whether implicit self-concepts, attitudes and stereotypes related to a variety of indicators of success and engagement in STEM such as: explicit math attitudes, anxiety and identity, current and anticipated participation in math, self-ascribed ability, and achievement on high stakes college gatekeeper tests like the SAT and ACT (Benbow, 1992; Maple & Stage, 1991; Marsh, 1992; Meece, Wigfield & Eccles, 1990; Ramist, Lewis, & McCamley-Jenkins, 1994; Singh, Granville & Kika, 2002; Smyth, 1995; Smyth & McArdle, 2004; Tai, Liu, Maltese & Fan, 2006).
5. Finally, we investigated whether implicit measures predict variation in math engagement that self-reports do not. If so, it would demonstrate the added practical and theoretical value of implicit measures for explaining variation in STEM engagement.

Method

Participants

5139 volunteers across the adult lifespan completed the study at a publicly-available Project Implicit website (http://implicit.harvard.edu/) between October 2001 and January 2003.[3] Project Implicit is a popular website at which visitors can participate in studies and learn about implicit social cognition for a variety of topics. Each year, more than one million study sessions are completed. Thousands of visitors come to the website each week referred by media reports, recommendations from others, assignments from class or work, and random surfing the Internet. The sample is heterogeneous, especially in terms of age, educational attainment and career field, but not representative of any definable population. Study of this sample substantially extends prior work conducted with a very selective collegiate sample.

The average age of the sample was 27 years (*SD* = 11), with half older than age 22, making this group much more age-diverse than typical convenience samples of college undergraduates. Women comprised 65%; Whites were 76%, Asians 6%, Blacks 5%, Hispanics 4%, and 9% were another ethnicity or race; 77% were U.S. citizens, 4% Canadian, 4% were from the U.K., and 15% from another country; 13% had a high school degree or less education, 51% had some college/university experience, 19% had a BA/BS or equivalent degree, and 17% reported an advanced degree.

Participants could report a "primary" undergraduate major and a "secondary" major or "minor" (list of options presented can be seen in online supplement). If either major/minor fit into the categories of math, engineering, natural sciences, or information technology then the participant was identified as a STEM major (*n* = 856, 19%). Among those with graduate training 13% reported a STEM field (*n* = 212).

Materials

Implicit Association Test (IAT). The IAT measures association strengths among concepts (e.g., *math* and *arts*) and attributes (e.g., *good* and *bad*) by way of a reaction time paradigm (see Nosek et al., 2007 for a review and Lane et al., 2007 for practical suggestions on IAT design).

Each participant completed a random selection of three of five IATs in a planned incomplete design. With the large sample, this approach enabled inclusion of a wide variety of measures without putting a significant time burden on individual participants. One of the IATs measuring implicit gender identity (associations between male/female and self/other) is not central to the goals of this report and is not discussed further. Of the remaining four IATs, three were modeled after ones introduced by Nosek, et al. (2002) measuring *implicit attitudes* (associations between math/arts and good/bad), *implicit academic identity* (associations between math/arts and self/other), and *implicit stereotyping* (associations between math/arts and male/female; see Table 1). New to this report is an IAT designed to measure *implicit math anxiety* (associations between math/arts and anxious/confident). The IAT procedures followed the recommendations of Nosek and colleagues (2007) and Nosek, Greenwald, and Banaji (2005).

The IAT is a relative measure indicating associations for one topic (math) compared to another (e.g., arts). A random third of participants were assigned to the math vs. arts contrast for each IAT (modeled on Nosek et al., 2002), another third received math vs. verbal, and the other third received math vs. furniture. Arts and verbal were selected as natural academic complements to math. Furniture was selected as a contrast that is irrelevant to academics and does not have any obvious gender stereotypes so as to test whether the observed effects were math-relevant and not exclusively a function of the verbal/arts contrasts (areas that are stereotypically associated with women; Beyer, 1999). We included dummy coding for the contrast category conditions in the reported inferential tests and found that contrast category (arts, verbal, or furniture) did not alter the substantive results. As such, for space and simplicity we do not report these results in the text, but complete information about the contrast category analyses is included in the supplementary materials available at http://briannosek.com/.

Each IAT was scored with the *D* algorithm recommended by Greenwald, Nosek, and Banaji (2003), which calculates the difference in the participant's average response latencies for the two critical conditions and is divided by the participant's overall variation (SD) in response latencies. The result is an individual effect size similar to Cohen's *d* with a possible range of scores from -2 to +2 (Nosek & Sriram, 2007). A score of zero indicates that the participant was equally fast categorizing, for example, math with good (and arts with bad) as math with bad (and arts with good). Positive values indicate relatively more favorable associations with math – i.e., faster categorizing of math with good than bad (attitude), of math with self than other (identity), and of math with confident than anxious (anxiety). For the stereotype IAT, positive values indicate stronger associations of math with male than with female.

Self-report measures. Participants answered a selection of questions designed to quickly tap key constructs of math engagement that have been widely identified in the academic literature: math attitude, math identity (i.e., "I am a math person."), confidence/anxiety, self-perceived ability, and expectations to participate in math (e.g., Aiken & Dreger, 1961; Betz & Hackett, 1983; Fennema & Sherman, 1976; Hyde, Fennema, Ryan, Frost & Hopp, 1990; Ingles et al., 1992; Linn & Hyde, 1989; Maple & Stage, 1991; Marsh, 1993; Meece, Wigfield & Eccles, 1990; Nosek, Banaji, & Greenwald, 2002; Parsons, 1983; Suinn & Edwards, 1982; Wigfield & Meece, 1988). Full text of questions and response options is listed in the online supplement.

A bipolar question type was fashioned as a direct corollary to the comparative structure of each of the implicit measures. For example, the corollary to the math-arts attitude IAT asked, "*Do you prefer math or arts?*" and provided nine response options ranging from "Strongly prefer math" to "Strongly prefer arts." Participants also provided attitudinal warmth ratings separately for math and for the randomly-assigned contrast category (arts, verbal or furniture) on 11-point scales ranging from "very cold feelings" to "very warm feelings."

Also, a small set of items measured self-reported math anxiety ("I feel nervous about doing math," "I am scared of advanced math topics"; α = .79), math identity ("Compared to other subjects, math is important to me," "I feel less of a commitment to math than to other academic domains" [reverse coded], "I identify with math more than with other subjects," α = .85), math stereotyping ("Men are better at math than women are," "Women can achieve as much as men in math" [reverse coded]; α = .60),[4] self-attributed math skill ("Compared to other subjects, I am very good at math," "Compared to other people, I am very good at math," α = .84), and math participation, past, present and future: "I have a lot of experience doing math," "Math is part of my daily activities," "I expect to use my math skills in the future"; α = .72. These items had four-point rating scales: "strongly disagree" (-1.5), "disagree" (-0.5), "agree" (0.5), and "strongly agree" (1.5). Items comprising each construct were averaged to create a single index.

College admission test reports. Participants who took the ACT or SAT standardized exams reported their scores for the subscales SAT-math and SAT-verbal (*n* = 1863; ranges 200-800) and ACT-math, ACT-science, ACT-English, and ACT-reading (*n* = 721; ranges 1-36). Comparative math-verbal/English score was calculated as the difference between the SAT scales and between ACT-math and ACT-English. Research shows that self-reports of achievement test scores are highly correlated with actual scores (*r* = .92; Smyth & McArdle, 2004; see also Cole & Gonyea, 2010).[5]

Procedure

Visitors to Project Implicit consented to participate in a study about "Academic Preferences." Recruiting materials did not provide any additional information about the particular topics of interest (i.e., math, stereotypes), or hypotheses. The order of self-report measures and IATs was randomized. Each participant completed a random three of five IATs: gender identity, academic attitude, academic identity, academic anxiety, and gender stereotyping. The order of the three IATs was also randomized. A demographics questionnaire was administered last. The order of measures had no effect on the results reported in this article.

Results

Sex differences in implicit attitude, identity, anxiety, and stereotyping

Summary results for each of the measures separated by participant gender are presented in Table 2. The IAT *D* score is an effect size comparison of one sorting condition (e.g., math with male and arts with female) versus the other (math with female and arts with male). Larger differences in average response latency for one condition versus the other results in a *D* score more distant from zero. Nosek et al.'s (2002) observations concerning implicit attitudes, identity and stereotyping with Yale undergraduates were replicated with this large, heterogeneous sample, and extended the observations to implicit anxiety associations. Women showed weaker implicit positivity toward math than did men ($t(2924) = 11.87$, $p < .0001$, $d = .44$), weaker implicit identification with math ($t(2957) = 10.07$, $p < .0001$, $d = .37$), and stronger implicit math anxiety ($t(2980) = 12.46$, $p < .0001$, $d = .46$). Also, both men and women evidenced strong implicit gender stereotypes associating math with male (*d*'s = .65 and .54). Men's math=male stereotyping was statistically stronger, but the magnitude of the gender difference was small ($t(2947) = 2.25$, $p = .02$, $d = .08$).

Explicit measures. Self-reported attitudes, identity, stereotyping and other indices of math engagement conformed to a similar pattern. Women consistently reported less positivity toward, and identification with, math than did men, both relative to other domains and in absolute terms (Table 2). Men reported somewhat higher scores on standardized math and science exams than did women. No gender differences, or effects slightly favoring women, were observed for verbal and English subtests of the standardized exams.

Relations among implicit STEM cognitions

We expected that implicit attitudes, identity, and anxiety (reverse-coded) measures would be positively correlated because of a common assessment of *favorability* toward math compared to other topics. Correlations among these measures are presented in Table 3 and the expected positive relations are observed for both men and women. On the other hand, according to cognitive consistency principles, the implicit math-male stereotype should have opposite relations with implicit math favorability for men and women (Greenwald et al., 2002; Nosek et al., 2002). For women, associating math with males more than with females should be negatively related to favorability toward math. This is the pattern we observed: among women, stronger implicit stereotyping of math as male was associated with more negative implicit attitudes toward math ($r = -.55$, $p < .0001$), weaker implicit identification with math ($r = -.47$, $p < .0001$), and stronger implicit math anxiety ($r = -.43$, $p < .0001$). For men, we expected that stronger associations of math with male should relate to stronger favorability toward mathematics. However, the relations between implicit stereotyping and implicit math attitudes, identity, and anxiety were quite weak for men, suggesting that the stereotype is more relevant for women's favorability toward mathematics than for men's (Table 3; see also Nosek et al., 2002).

Relations among explicit STEM cognitions. As was observed for the implicit measures, explicit attitudes, identity, and anxiety (reverse-coded) were positively correlated, suggesting a common factor of math favorability (Table 3). The relation between math favorability and stereotyping, however, was notably weaker with the explicit measures than with their implicit counterparts. Whereas implicit stereotype was strongly related to the implicit measures of math favorability for women (average $r = -.48$), explicit stereotype was less strongly related to explicit math favorability (average $r = -.17$). For men, holding stronger explicit stereotypic associations of math with male was associated with stronger explicit favorability toward math (average $r = .16$).

Because of their strong inter-relations, for participants who, by random assignment, did more than one of the “favorability” IATs – math attitude, math identity, and math anxiety (reverse-coded) – the scores were averaged into a single implicit math favorability index. Positive values indicate greater implicit favorability toward math compared to the alternative category. All reported results were similar when testing each of the favorability IATs separately.

Investment in STEM: Comparison of STEM graduate, STEM undergraduate, and other majors

Selecting a STEM field for an undergraduate major, or for graduate training, is a substantial personal investment in science and mathematics. Most STEM majors involve rigorous mathematics training. As such, we anticipated that men and women who selected STEM majors would exhibit greater implicit favorability toward math compared to people who chose other majors, and that participants selecting to pursue graduate training in STEM would show the most favorability toward math. Participants were divided into three groups: STEM-graduate (those who reported pursuing a STEM graduate degree), STEM-undergraduate (of the remaining participants, those who reported pursuing an undergraduate STEM degree), and other (of the remaining participants, those who reported pursuing a college degree). This grouping was treated as a categorical variable with STEM-graduate majors being the most committed to math and science and ‘other’ majors the least. While some of the STEM-undergraduate majors may eventually pursue graduate training, they had not done so yet.

Implicit favorability toward math by sex and major. Data were analyzed as an ANOVA with sex (male, female), major (not STEM, STEM-undergrad, STEM-graduate), and their interaction as predictors.[6] Figure 1 presents implicit math favorability by the three major categories separated by gender. There was a main effect of sex indicating, as before, that women were less implicitly favorable toward math than were men (F (1, 4442) = 29.40, p < .0001, d = -.16). Also, there was a main effect of major indicating that people who selected a STEM major, especially for graduate training, were more implicitly favorable toward math than were others (F (2, 4442) = 88.74, p < .0001, d = .28). Among non-STEM majors, women were substantially more negative toward math than were men (d = .38); that sex gap was slightly weaker among undergraduate STEM majors (d = .33); and it was less than half that magnitude among graduate STEM majors (d = .14).[7]

Implicit stereotyping by sex and major. While cognitive balance principles predict that both male and female STEM majors will have greater favorability toward math than people with other majors, they predict divergent effects for implicit stereotyping of math as male. For male STEM majors, the prevalent stereotype and their own everyday practice in the field reinforces their association of male with mathematics. For female STEM majors, a cognitively consistent identity that includes strongly associating oneself with mathematics would require either a diminished association of math with male or of the self with female. These relations were examined with an ANOVA model with sex, major, and their interaction as predictors of implicit stereotyping. There was no main effect of major (p = .20), but there was a significant effect of sex (F (1, 2605) = 22.48, p < .0001, d = .19), and a significant sex X major interaction (F (2, 2605) = 12.05, p < .0001, d =.14). The interaction is illustrated in the lower panel of Figure 1. Whereas male (*M* = .26) and female (*M* = .25) non-STEM majors did not differ in strength of implicit stereotype, men who pursued undergraduate (*M* = .35) or graduate (*M* = .29) STEM training had stronger implicit stereotypes, and women who pursued undergraduate (*M* = .10) or graduate (*M* = .04) STEM training showed much weaker implicit stereotypes. One interpretation of this effect is that female STEM majors maintain cognitive balance by somehow reducing or eliminating the implicit stereotype of math as male. An alternative (or simultaneous) causal possibility is that those women with weak or reversed implicit stereotypes may be the most likely to pursue and obtain STEM degrees in the first place.

Predicting explicit STEM attitudes, identity, participation, perceptions of ability and standardized test scores with implicit STEM cognitions

The preceding sections examined group comparisons of implicit STEM cognitions and their interrelations according to theories of cognitive consistency. Women in STEM showed less implicit stereotyping of math and greater implicit favorability toward math than did non-STEM women. This implies that implicit cognitions may be related to other indicators of math engagement. This section examines whether implicit STEM cognitions predict self-reported engagement and achievement in mathematics.

Implicit math cognitions predict explicit math cognitions. Table 4 presents implicit favorability and stereotyping correlated with a variety of explicit math-related cognitions and achievement measures separated by participant sex. The first five rows involve self-report measures that contrast math with a comparison category to parallel the IAT design. Implicit favorability toward math was positively related to relative explicit attitudes, identity and anxiety (reverse-coded) for both men and women (average *r* = .45; range .29 to .51). Implicit and relative explicit stereotyping measures were more modestly positively related, though similarly, again, for men (*r* = .21) and women (*r* = .18). Implicit stereotyping was negatively related to relative explicit math preferences, identity and anxiety for women (average *r* = -31; range -.21 to -.36), but slightly positively related to those measures for men (average *r* = .09; range .08 to .10).

Implicit math cognitions were also compared with explicit math engagement measures that did not have a comparative (arts, verbal, or furniture) contrast. Again, implicit favorability toward math was associated with more positive explicit math attitude, explicit math identity, and less explicit math anxiety for both men and women (average *r* = .36; range .25 to .48). And, implicit stereotyping was associated with less positive math attitude, identity, and greater anxiety for women (average *r* = -.21; range -.18 to -.27), but the opposite relationship (more weakly) for men (average *r* = .10; range .09 to .13).

In summary, following cognitive consistency principles, stronger implicit math favorability correlated with explicit favorability toward math for both men and women, and stronger implicit stereotypes correlated with less explicit favorability toward math for women, and slightly more favorability toward math for men.

Implicit favorability and stereotyping predict participation in math, and self-ascribed skill. Men and women with greater implicit favorability toward math reported more participation in math and rated their own math skills as higher than did those with less implicit favorability toward math (Table 4). At the same time, women with stronger implicit stereotypes reported less participation in math and less self-ascribed skill than did women with weaker implicit stereotypes. Implicit stereotyping was weakly positively related to participation and self-ascribed skill for men.

Implicit favorability and stereotyping predict scores on high-stakes college admission exams. SAT scores were reported by $n = 1211$ participants and ACT scores were reported by $n = 462$. Men and women with stronger implicit favorability for math performed relatively better on the math than the verbal/English portions of the SAT and ACT (average $r = .30$; range .28 to .32), and that relationship persisted, though more weakly, when looking at math scores in isolation (average $r = .15$; range .11 to .20). Further, the relationship between implicit stereotyping and test scores was in opposing directions for men and women. Women who more strongly associated math with male did worse on the SAT and ACT math tests than did women with weaker stereotypes (SAT $r = -.19$; ACT $r = -.18$), but men evidenced a non-significant relationship in the opposite direction (SAT $r = .19$; ACT $r = .12$, *not significant*).

Implicit stereotypes account for math engagement and achievement beyond that explained by self-reported stereotyping

Implicit and explicit stereotypes were weakly related to one another, but both related to a variety of measures of math engagement. At a time when explicit expressions of stereotypical beliefs are publicly unacceptable, it may be that implicit stereotypes have predictive validity beyond what is accounted for by stereotypes that people are willing and able to report.[8] Table 5 summarizes 13 hierarchical linear regressions demonstrating the incremental predictive validity of the implicit over explicit stereotypes. For each hierarchical regression, sex, explicit stereotype, and the sex X explicit interaction were entered in a first step, then implicit stereotypes and the sex X implicit interaction were entered as a second step. Under this procedure, implicit stereotypes had to predict variance beyond that already accounted for by self-reported stereotypes in order to be a significant predictor. The dependent variables were explicit math attitudes, math identity, math anxiety either toward math alone or math relative to the comparison category (arts, verbal or furniture), participation in math, self-ascribed math skill, and SAT and ACT math scores (absolute or relative to SAT verbal or ACT English, respectively).

In twelve of the thirteen regression models (excepting only the prediction of ACT math alone), the interaction of sex and implicit stereotype significantly predicted the math engagement measures beyond the prediction afforded by explicit stereotype. To unpack the interaction effect, we removed the sex variable and reran the final step of the regressions with implicit and explicit measures as simultaneous predictors separately for men and women. For men, stronger stereotypes of math as male were consistently positive predictors of math engagement and test scores, both explicitly (median $\beta = .10$, range = .04 to .14; 9 of 13 regression estimates $p < .05$) and implicitly (median $\beta = .10$, range = -.11 to .20; 8 of 13 regression estimates $p < .05$). For women, stronger stereotypes of math as male were consistently negative predictors of math engagement and test scores, both explicitly (median $\beta = -.13$, range = -.24 to .01; 9 of 13 regression estimates $p < .05$) and implicitly (median $\beta = -.24$, range = -.27 to -.06; 11 of 13 regression estimates $p < .05$).

The regression analyses in Table 5 also show that implicit stereotype was consistently a *stronger* predictor of math engagement and test scores than was explicit stereotype. In eleven of the thirteen models (not for ACT math alone or for explicit math anxiety), the standardized coefficient for the sex X implicit stereotyping predictor was larger than the sex X explicit stereotyping predictor even though it was entered in a second step. The separate follow-up tests for men and women revealed that the stronger predictive validity of implicit stereotype was due more to its effect for women (implicit median β = -.24, explicit median β = -.13), than for men (implicit median β = .10, explicit median β = .10).

Discussion

Attitudes and stereotypes about math are important predictors of STEM engagement (Halpern et al., 2007; Hyde et al., 1990). However, people are often reluctant to report stereotypes, or people may even possess such associations without knowing or being able to report them. As a consequence, stereotypes may have a role in shaping STEM engagement and achievement without people endorsing the stereotypes, or even being aware of having them.

We found that implicit measures of favorability toward math – implicit attitudes toward math, identification with math, and associating math with confidence more than with anxiety – and gender stereotypes about math – implicitly associating math with male more than with female – predicted a variety of indicators of math engagement and achievement, and may provide substantial value for education theory and evidence for the mechanisms that account for the gender gap in STEM involvement.

In particular, with a large, heterogeneous sample, we observed that women were less implicitly favorable toward math than were men, and that both men and women implicitly associated math with male more than with female. Further, the relations among implicit measures conformed to theories of cognitive consistency: women who associated math with male more strongly were more implicitly unfavorable toward math than were women whose math-male associations were weaker. This implicit stereotype was only modestly correlated with participants' self-reported stereotypes, suggesting that the explicit and implicit stereotype constructs differ. Indeed, implicit stereotypes predicted a variety of indicators of math engagement and achievement beyond what was accounted for by explicit stereotypes. For women, implicitly associating math with male predicted reporting more negative attitudes toward math, less identification with math, having more anxiety about math, ascribing less skill in math to oneself, participating less in math activities—including pursuing a STEM degree—and performing worse on high-stakes college admission tests – the ACT and the SAT.

For men and women in STEM, cognitive consistency was maintained with STEM men and women showing opposing tendencies for implicit stereotypes. Men in STEM showed stronger associations of STEM with math than all other groups, and women in STEM showed weaker associations of STEM with math than all other groups. This divergence in implicit stereotyping between men and women in STEM domains could contribute to subtle ways in which the STEM workplace and education climate makes it more difficult for women to develop a sense of belonging and ultimately stay engaged in the field (Valian, 1998).

These findings show that implicit attitude and stereotype measurement is valuable in accounting for variation in engagement with mathematics, and especially for sex differences. It further suggests that, to the extent that stereotypes may shape math engagement and achievement, this mechanism may operate "under the surface."

Women's unwillingness to endorse explicit stereotypes that math and science are male domains does not mean that the stereotype will have no impact on their self-concept and behavior. The fact that the stereotype is learned and encoded in memory gives it the opportunity to subtly shape the interest and involvement of girls and women in STEM.

Identifying causal relations between implicit cognitions and math engagement

While we emphasized a directional interpretation of our results, these correlational data cannot clarify the causal relations between implicit cognitions and indicators of math engagement and achievement. The term "prediction" in this article is a statement of the analysis, not an indication of a determined causal relation. In fact, we hypothesize that the causal paths are bidirectional (see also Nosek, Smyth, et al., 2009). On one hand, women with stronger implicit stereotypes of math as male and implicitly more unfavorable evaluations of math should be, theoretically, more prone to feeling like an outsider in STEM-related disciplines, less likely to select math-related courses for additional training, more vulnerable to effects of stereotype threat in challenging math achievement contexts, and more likely to leave STEM-majors and careers than women with weaker implicit stereotypes and more favorable implicit attitudes—even if their explicit reports are the same (Kiefer & Sekaquaptewa, 2007a, 2007b).

On the other hand, designating oneself as a STEM-major is a potent psychological act of self-identification. According to Greenwald et al. (2002), self-associations are at the epicenter of our networks of concept associations, and have greater leverage to influence related associations. For women, identifying as a STEM major may spur mental adaptation toward cognitive consistency, entailing weakening of the association between self and female, or of that between math and male, or both. Given a well-established link between self and female, it is the association of math with female that is more likely to strengthen. Acts and experiences strengthening for girls and women the connection between self and math are expected under cognitive consistency principles to strengthen the counter-stereotypical association between math and female (Nosek et al., 2002; Gawronski, Deutsch, Mbirkou, Seibt & Strack, 2008). Actions such as taking a STEM class, or becoming a STEM major, may produce the cognitive orientation toward mathematics rather than be a consequence of it. Substantially more experimental and developmental findings must accumulate along the way to understanding how implicit cognitions and STEM-related outcomes develop and interact over time.

Recent findings of Cvencek, Meltzoff, and Greenwald (2010)—that implicit stereotyping of math as male was normative in a sample of elementary school students prior to any actual gender differences in achievement—suggest that implicit stereotype learning occurs early, well in advance of middle school when self-concepts and decisions related to the pursuit of higher level math and science begin to cement (Tai, Liu, Maltese & Fan, 2006). Without being able to introspect on its strength or origin, an implicit stereotype of math as male may, to the woman possessing it, be experienced as a vague feeling of "not belonging" in math, and undermine efforts to pursue and persist in behaviors that would result in long-term engagement and high achievement. Our results add evidence concerning the potential educational impact of implicit stereotypes to that recently provided by van den Bergh et al. (2010) with respect to implicit attitudes. The combination suggests that further inclusion of implicit measures and concepts from implicit social cognition is likely to enrich models of academic motivation, self-concept, and self-efficacy. Further, while our focus was on math and science, there are other relevant and important stereotypes and skill in other categories such as reading that are tightly integrated with the development of interests and self-competence (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). A fully integrative account will incorporate these as well to clarify how implicit cognitions are relevant to academic engagement and achievement.

Limitations

While the effects are strong and compelling, there are a variety of factors to keep in mind for interpreting these effects. First, we focused on a single implicit measurement procedure – the Implicit Association Test – as our operationalization of implicit cognition. Its validity is evident in the results and its voluminous literature (see DeHouwer et al., 2009; Nosek et al. 2007), but it is possible that employing a diversity of implicit measures will improve the measurement and assessment of implicit STEM cognitions. Second, while the sample is large and heterogeneous, it is not representative of any population and derives from a convenient source of web volunteers. These results add to the large body of evidence for the validity of web-based data collection (e.g., Nosek, Smyth, et al., 2007; Nosek, Smyth, et al., 2009; Ranganath & Nosek, 2008), but it will be useful to further expand sampling and setting contexts to establish the generality of these effects. In particular, using child-friendly adaptations of the IAT (Baron & Banaji, 2006; Cvencek, et al., 2010) will be particularly useful for furthering the investigation of the development of implicit social cognitions from early childhood through adulthood. Third, in order to show that implicit cognitions could predict a wide variety of indicators of math engagement, and given practical time constraints of data collection, we used very simple assessments of constructs. Future work could make good use of the rich measures of STEM identity, motivations, self-efficacy, participation, and other factors that are theorized to be critical in academic achievement to unpack the nuances of when implicit measures will predict particular aspects of STEM engagement. The present results suggest that such efforts will be productive.

Implications for interventions to improve STEM engagement

The present research adds to the network of evidence that implicit STEM cognitions contribute to STEM engagement. For practitioners, the present results do not directly imply an intervention to address the role of implicit cognitions, but it does point to an interesting possibility: interventions designed to improve students' STEM engagement may have an impact in ways that are not detectable with self-reported evaluation measures. In other words, interventions may work on a level that escapes students' ability to report it. A recent finding from Stout and colleagues (2010) is a tantalizing example of this possibility. Women that had a female as opposed to male instructor for their calculus course had significantly more positive implicit attitudes toward math, stronger implicit identification with math, and actually expected that they would perform better in the course. These effects were moderated by the degree to which the female students identified with their female (as opposed to male) instructor. All of this occurred without any change to the women's self-reported stereotypes about math – i.e., the women's explicit beliefs did not change even though their implicit associations did. This suggests that incorporating implicit measures into the evaluation of education interventions could increase the sensitivity of identifying when and how such interventions are effective. A student's failure to report that an intervention was effective may mislead researchers and practitioners to prematurely dismiss an intervention. Its effectiveness may have escaped the student's awareness.

Conclusion

Conscious experience is a compelling but incomplete reflection of the mind. Behavior is influenced by thoughts intended and unintended, and mental processes that are known and unknown. Implicit measurement allows assessment of thoughts and feelings about academic domains that may not be measureable by introspection and self-report, but are clearly intertwined with important STEM-related behavior. This article establishes the utility of implicit measurement in accounting for important math outcomes such as attitude, self-concept, participation, self-ascribed skill, and achievement. It empirically underscores the growing consensus that theories from implicit social cognition dovetail with theory and evidence in education research. The critical next extension of this work is longitudinal research to determine whether implicit cognitions exert a causal influence on STEM participation, and to pursue stronger theoretical integration of theories about STEM engagement in education research with the relevant theory and evidence from implicit social cognition.

Footnotes

[1] However, like any psychological construct, it is important to remember that each measure is just a single operationalization of the concept. Measurement diversity provides significant value in implicit social cognition research as a means of clarifying which findings are construct general versus measurement specific.

[2] For example, a Google Scholar search of *American Educational Research Journal* and *Journal of Educational Psychology* between 2000 and 2009 did not yield a single occurrence of the phrases "implicit [or unconscious] bias, attitude, or stereotype, or "implicit measure."

[3] Participants had to reach the demographics page at the end of the study and answer the participant gender question to be included in the present analyses. 351 sessions were dropped because the participant had already completed some or all of the measures previously, and an additional 255 sessions were dropped because the participant had two or more IAT performances that met exclusion criteria for too many fast responses (>10% overall, >25% in any critical block) or errors (>30% overall, >40% in any critical block; Nosek et al., 2007). Participants with partial completion of measures were retained accounting for variation in sample sizes reported in Tables 2 and 5. The effects did not differ substantively using only completed sessions.

[4] Note that alpha is strongly influenced by the number of items in the measure. The alpha level of .60 corresponds to a correlation of .43 between the two items showing strong correspondence. Further, analyzing each item separately shows effects highly consistent with those reported with the aggregate measure here.

[5] Math and verbal SAT score means in this sample were substantially higher than national averages. Women averaged 592 (*SD* 124) in math and 608 (*SD* 116) in verbal, compared with the respective national averages of 498 and 502 (both *SD*s 109; College Board, 2001). Among men, mean math and verbal scores were 637 (*SD* 119) and 620 (*SD* 112), compared with national

means of 533 (*SD* 115) and 509 (*SD* 112). While the accuracy of the self-reported scores cannot be verified, we observed the expected pattern of higher scores for STEM majors compared with non-STEM majors, especially in math, as well as theoretically-derived relations with other measures – including implicit measures.

[6] As in all other inferential tests, the comparison category (arts, verbal, or furniture) was included as a covariate with its main effect and interactions with gender and major estimated.

[7] The sex X major interaction was not significant in this model ($p = .20$), however, treating major as a continuous variable – such that graduate level STEM majors reflect greater investment in STEM than undergraduate STEM majors – was reliable but weak ($p = .04$). That is suggestive, but incomplete evidence, that the sex gap in math favorability is weaker among the most STEM invested.

[8] For space considerations, analyses showing incremental predictive validity of implicit math favorability appear in supplementary materials at http://briannosek.com/.

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Table 1. Description of Implicit Association Tests

Topic	Target concepts	Attribute concepts	Interpretation
Implicit Attitude	Math – Arts*	Good – Bad	Positive values indicate an implicit preference for math compared to arts
Implicit Identity	Math – Arts	Self – Other	Positive values indicate an implicit identification with math compared to arts
Implicit Anxiety	Math – Arts	Confident – Anxious	Positive values indicate stronger associations of math with confident (and arts with anxious) compared to math with anxious (and arts with confident)
Implicit Stereotype	Math – Arts	Male – Female	Positive values indicate stronger associations of math with male (and arts with female) compared to math with female (and arts with male)

Note: * The contrast category to math was randomly assigned between subjects to be arts, verbal, or furniture.

Table 2. Descriptive statistics for men and women and magnitude of sex differences.

	Men (N = 1774)				Women (N = 3356)				Gender Diff
Measure	N	Mean	SD	d	N	Mean	SD	d	Cohen's d
Relative measures									
Implicit attitude	1000	-.15	.47	-.32	1926	-.37	.47	-.79	-.47
Implicit identity	1022	.09	.45	.21	1937	-.08	.45	-.18	-.39
Implicit anxiety	1004	-.09	.41	-.21	1978	-.29	.42	-.68	-.47
Implicit gender stereotyping	1028	.28	.42	.65	1921	.24	.44	.54	-.09
Explicit attitude	1747	-.26	2.63	-.10	3317	-1.33	2.51	-.53	-.40
Explicit identity	1748	.02	2.46	.01	3310	-.87	2.43	-.36	-.56
Explicit anxiety	1749	-.35	1.71	-.21	3316	-.92	1.69	-.54	-.32
Explicit gender stereotyping	1745	.87	1.19	.73	3312	.76	1.17	.65	-.09
Feelings of warmth difference	1736	-.66	3.61	-.18	3305	-2.07	3.66	-.57	-.37
Math-only measures									
Explicit math identity	1754	-.03	.76	-.04	3330	-.25	.75	-.33	-.27
Explicit math anxiety	1753	.23	.78	.30	3326	-.06	.83	-.07	-.34
Math participation	1753	.37	.62	.59	3329	.25	.62	.41	-.17
Self-acscribed math ability	1753	.13	.76	.17	3327	-.11	.79	-.13	-.28
Explicit math stereotyping	1749	-.54	.60	-.89	3328	-.84	.56	-1.51	-.50
Warmth for math	1737	5.93	2.41	.	3305	5.16	2.57	.	-.29
Achievement measures									
SAT math - verbal difference	647	13.6	99.2	.14	1211	-20.4	93.4	-.22	-.34
SAT math	652	644.1	113.1	.	1229	605.4	112.5	.	-.33
SAT verbal	647	632.4	100.8	.	1211	629.1	104.8	.	-.03
ACT math - English difference	253	-.5	5.4	-.09	462	-2.8	5.2	-.54	-.40
ACT math	255	25.7	7.3	.	463	24.3	6.7	.	-.18
ACT English	260	26.0	7.4	.	469	26.9	6.8	.	.12
ACT reading	244	26.9	7.3	.	449	27.2	6.8	.	.04
ACT science	245	26.4	6.7	.	442	24.9	6.5	.	-.22

Note: For relative measures, attitude, identity, and anxiety measures are coded such that higher values indicate more favorability toward math compared to the contrast category; Higher gender stereotyping indicates stronger male-science and female-contrast associations than the reverse. Cohen's *d*'s calculated for scores with a rational zero-point (e.g., no preference or no difference in achievement). Last column indicates magnitude of the sex difference (-1=male, +1=female) estimated from regressions that covaried variance due to the contrast category. All $|d|$s > .04 are significant at α=.05.

Table 3. Correlations among implicit measures (top panel) and explicit measures (bottom panel) for women (left of diagonal) and men (right of diagonal).

Implicit measures	attitude	identity	anxiety	gender stereotyping
attitude	.	.39	.52	-.10
identity	.53	.	.38	-.02
anxiety	.55	.48	.	.14
gender stereotyping	-.55	-.47	-.43	.
Explicit measures	attitude	identity	anxiety	gender stereotyping
attitude	.	.88	.51	.17
identity	.84	.	.51	.15
anxiety	.56	.52	.	.15
gender stereotyping	-.16	-.15	-.19	.

Note: Attitude, identity, and anxiety measures are coded such that higher values indicate more favorability toward math compared to the contrast. Higher gender stereotyping indicates stronger male-science and female-contrast associations than the reverse. In top panel female Ns range from 912-973, male Ns range from 467 to 517 (all $|r|$s $< .07$ are ns for $\alpha=.05$). In bottom panel female Ns range from 3297-3310, and male Ns range from 1737 to 1744 (all $|r|$s $< .03$ are ns for $\alpha=.05$).

Table 4. Correlations between implicit, explicit, and achievement measures for women and men.

	Women		Men	
	implicit favorability	implicit gender stereotyping	implicit favorability	implicit gender stereotyping
Relative explicit measures				
Attitude	.51	-.35	.50	.09
Identity	.50	-.36	.51	.08
Anxiety	.34	-.21	.29	.10
Gender stereotyping	-.15	.18	.05	.21
Feelings of warmth difference	.50	-.36	.48	.10
Math-only explicit measures				
Math identity	.39	-.27	.48	.13
Math anxiety	.28	-.18	.25	.09
Math participation	.24	-.18	.27	.08
Self-acscribed math ability	.32	-.22	.32	.12
Math stereotyping	-.12	.13	.04	.14
Warmth for math	.37	-.26	.38	.12
Achievement measures				
SAT math - verbal difference	.30	-.19	.28	.19
SAT math	.13	-.11	.20	.15
ACT math - English difference	.32	-.18	.29	.12
ACT math	.14	-.09	.11	.02

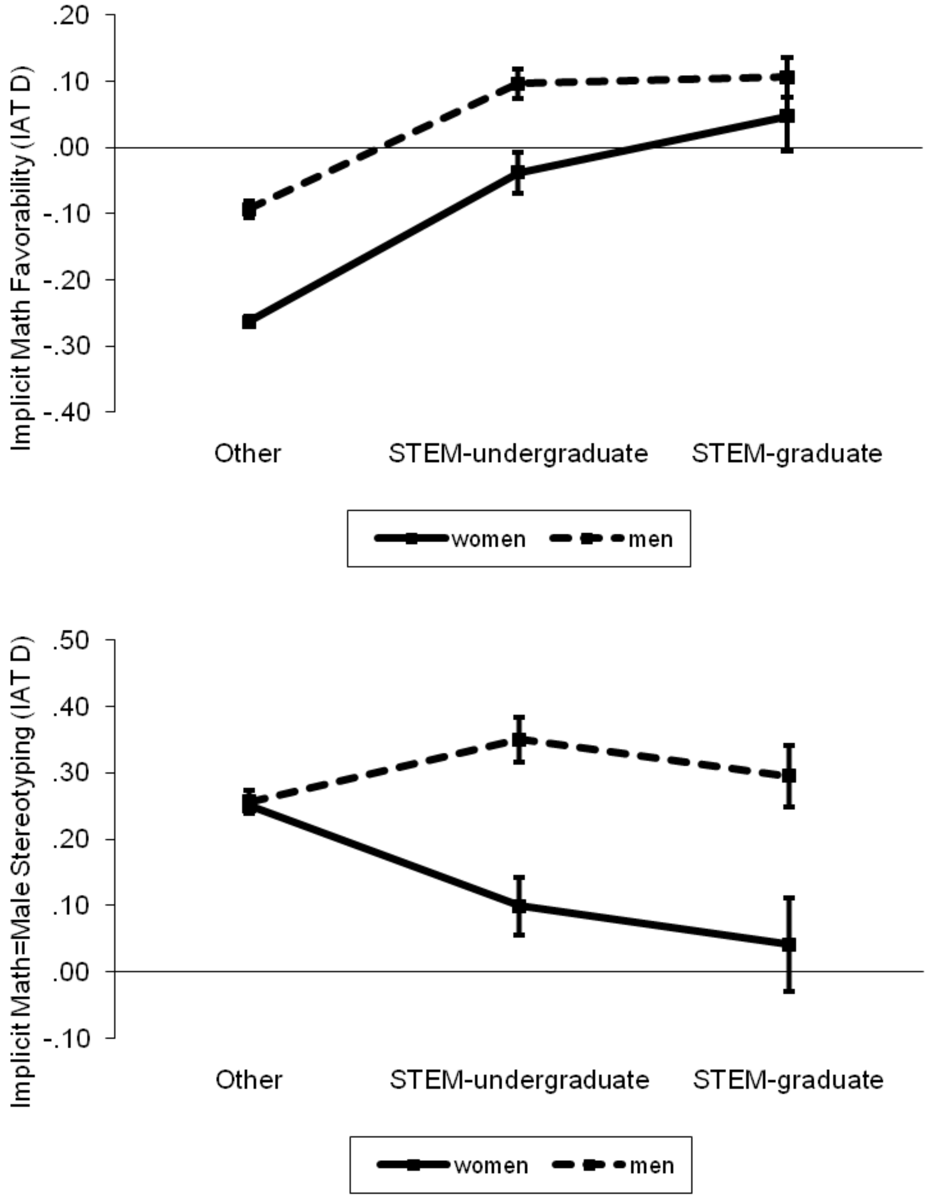
Note: Implicit favorability is an average of the implicit attitude, identity, and anxiety measures (each participant completed 1 to 3 of these measures). Relative explicit measures involved a contrast between math and, randomly, either arts, verbal, or furniture. Attitude, identity, and anxiety measures are coded such that higher values indicate more positivity toward math compared to the contrast. Higher relative gender stereotyping indicates stronger male-science and female-contrast associations than the reverse, while the math-only stereotype is a composite of two items asking only about gender and math associations. Correlations are positive for both men and women with implicit favorability indicating that stronger implicit favorability is associated with more explicit math engagement for both men and women. Correlations are in opposing directions for implicit stereotyping indicating that stronger math=male associations have opposite implications for men and women's math engagement. For top two panels, Female Ns range from 1903 to 3262, male Ns range from 984 to 1711 (all $|r|$s $< .05$ are ns for $\alpha=.05$, and ACT relations $< .10$). For achievement measures, Female Ns range from 261 to 1207, male Ns range from 135 to 634 (all $|r|$s $< .10$ are ns for $\alpha=.05$, and ACT relations $< .13$).

Table 5. Beta weights from hierarchical regressions of implicit and explicit gender-academic stereotypes predicting academic attitudes, identity, anxiety, participation, self-ascribed ability, and achievement on college admission exams.

		Step 1				Step 2		
Dependent Variables	N	sex	Explicit stereotype	sex X Explicit	R^2	Implicit stereotype	sex X Implicit	R^2
Relative Measures								
Explicit attitude	2909	-.21***	-.08***	-.11***	.11	-.06**	-.25***	.17
Explicit identity	2910	-.18***	-.08***	-.10***	.13	-.06**	-.24***	.18
Explicit anxiety	2913	-.16***	-.08**	-.13***	.05	-.06*	-.16***	.08
Feelings of warmth difference	2902	-.19***	-.09***	-.13***	.12	-.07***	-.25***	.18
SAT math-verbal difference	1043	-.20***	.02	-.08*	.05	.01	-.23***	.09
ACT math-English difference	390	-.21**	.05	-.18***	.08	-.05	-.19**	.11
Math only measures								
Explicit math identity	2921	-.15***	-.09***	-.11***	.04	-.06***	-.25***	.09
Explicit math anxiety	2921	-.20***	-.17***	-.12***	.07	-.17***	-.10***	.09
Feelings of warmth toward math	2903	-.17***	-.12***	-.12***	.05	-.06**	-.23***	.10
Math participation	2922	-.12***	-.09***	-.10***	.04	-.03	-.17***	.06
Self-ascribed math ability	2921	-.18***	-.10***	-.14***	.06	-.05***	-.20***	.09
SAT math	1061	-.18***	.00	-.09**	.05	.03	-.13***	.06
ACT math	392	-.16*	-.18**	-.10*	.06	-.13	.01	.09
Median beta		-.18	-.09	-.11	.06	-.06	-.20	.09

Note: Sex coded -1 male, +1 female. All dependent measures coded such that higher values indicate stronger orientation toward math (versus the comparison category for relative measures). Each row summarizes two regressions – Step 1 with explicit stereotype and sex X explicit stereotype interaction as predictors; Step 2 adding implicit stereotype and sex X implicit stereotype as predictors. R^2 indicates the total variance explained in each step. Regressions also included dummy variables for the comparison category to math (arts, verbal, furniture) and interactions with sex, implicit and explicit stereotypes. Those beta's are suppressed on the table, but available in supplementary materials. The math-only explicit stereotyping measure was used as the predictor for these regressions. A similar table using the relative explicit stereotyping measure is available in the supplements (implicit stereotyping showed consistent incremental predictive validity there as well). The median beta in the bottom row indicates the average effect for each predictor across the dependent variables. * p < .05, ** p < .01, *** p < .001.

Figure 1. Implicit math favorability (top panel) and implicit gender-math stereotyping (bottom panel) for men and women separated by degree type: STEM graduate degree, STEM undergraduate degree, or other.



Note: Implicit math favorability is an average of attitude, identity, and anxiety measures (each participant completed 1 to 3 of these measures). Positive values indicate greater favorability toward math compared to contrast category. Group membership determined by highest pursued STEM degree. Error bars indicate standard error of the mean.