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Women in Science, Technology, Engineering, and Mathematics (STEM): An Investigation of Their Implicit Gender Stereotypes and Stereotypes' Connectedness to Math Performance

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Abstract In spite of many barriers facing women's enrollment in Science, Technology, Engineering, and Mathematics (STEM), some women are successful in these counter-stereotypic disciplines. The present research extended work primarily conducted in the United States by investigating implicit gender-STEM stereotypes—and their relation to performance—among female and male engineering and humanities students in Southern France. In study 1 ($N=55$), we tested whether implicit gender-math stereotypes—as measured by the Implicit Association Test (IAT; Greenwald et al. 1998)—would be weaker among female engineering students as compared to female humanities, male engineering and male humanities students. In study 2 ($N=201$), we tested whether this same results pattern would be observed with implicit gender-reasoning stereotypes (using a newly created IAT) and, in addition, whether implicit gender-reasoning stereotypes would be more strongly (and negatively) related to math grades for female humanities students as compared to the three other groups. Results showed that female engineering students held weaker implicit gender-math and gender-reasoning stereotypes than female humanities, male engineering and male humanities students. Moreover, implicit stereotyping was more negatively related to math grades for female humanities students than for the three other groups. Together, findings demonstrate that female engineering students hold weaker implicit gender-STEM stereotypes than other groups of students and, in addition, that these stereotypes are not necessarily negatively associated with math performance for all women. Discussion emphasizes how the present research helps refine previous findings and their importance for women's experience in STEM.

Keywords Implicit gender stereotypes · Women in Science, Technology, Engineering, and Mathematics · Math performance

Introduction

In many countries, including those from the European Union and in the United States, women are still underrepresented in Science, Technology, Engineering, and Mathematics (STEM) relative to men (European Commission 2006; National Science Foundation 2009). Women's underrepresentation in STEM has been a concern for decades in the U.S. (Rossi 1965) and, more recently, in France (De Peslouan 1974), but its causes remain debated (see Halpern et al. 2007 for an overview of this debate in North America). One explanation is the negative effect of gender stereotypes pertaining to women's perceived lower ability in domains such as mathematics and reasoning (Cejka and Eagly 1999; Davies et al. 2002). In line with this, research conducted in Germany and North America suggests that such gender-STEM stereotypes have the potential to undermine girls' and women's self-perceptions of ability, performance and interest in pursuing a career in counter-stereotypic (masculine) disciplines (Eccles 1987; Eccles et al. 1990; Gunderson et al. 2012; Jacobs 1991; C.M. Steele 1997;

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Tenenbaum and Leaper 2003; Tiedemann 2000; Wigfield et al. 1997). Some research conducted in France on stereotype threat—which corresponds to the threat of confirming a negative stereotype about one's group in a given ability domain—indicates that gender stereotypes can undermine girls' math achievement (Huguet and Régner 2007, 2009).

In the present research, we wanted to extend research primarily conducted in the United States by investigating implicit gender-STEM stereotypes—and their relation to performance—in France. More precisely, in two studies, our aim was to compare female engineering students' implicit gender stereotypes with those of female humanities students and, in the second study, to additionally examine how these stereotypes relate to math performance. For comparison purpose, male engineering and humanities students' stereotypes were also investigated in our research. The inclusion of French STEM (i.e., engineering) and non-STEM (i.e., humanities) samples, as well as women and men when investigating implicit gender stereotypes and their relation to performance represents a novel contribution for research on implicit gender stereotypes in particular, and for gender issues more generally.

Indeed, a focus on the few women who are successful in STEM (female engineering students), as compared to those who are not in STEM (female humanities students) will improve our understanding of determinants of women's counter-stereotypic success in STEM and, consequently, will help designing interventions that will remedy women's attrition rate. As a working hypothesis, we assume that there is something specific about French female engineering students' gender stereotypes as compared to their female humanities counterparts and that these stereotypes would be differentially related to STEM performance in the two samples. We also argue that implicit measures of stereotypes are particularly well suited to assess this specificity.

Often, research on women in STEM in the United States relied on explicit, self-report measures of gender stereotypes (Hartman and Hartman 2008; Cheryan and Plaut 2010). However, we chose to measure gender stereotypes implicitly, as has been done in German and U.S. research (Nosek et al. 2002; Steffens and Jelenec 2011; Stout et al. 2011; White and White 2006), because explicit measures are susceptible to motivational biases and introspective limitations (Greenwald and Banaji 1995; Hofmann et al. 2005). Such biases may be present in our samples given that research in France and in North America has shown that, at an explicit level, young students often reject the view that women have less math ability than men (Huguet and Régner 2009; J. Steele 2003). If responses on explicit stereotype measures are biased, it may be difficult to capture between-group differences because all groups are likely to report similar responses. In addition, implicit stereotypes are generally better predictors of behavioral outcomes (performance, vocational choices) than explicit stereotypes, as studies conducted among American, Asian, and European samples have shown (Kiefer and Sekaquaptewa 2007a, b; Nosek et al. 2009).

Implicit Gender-STEM Stereotypes and Academic Major

To make predictions regarding STEM and non-STEM women's implicit gender-STEM stereotypes in our studies, we will rely on Greenwald et al.'s (2002) Unified Theory. According to this theory, social knowledge can be represented as "a network of variable-strength associations among person concepts (including self and groups) and attributes" (Greenwald et al. 2002, p. 5). A stereotype can then be defined as the association of a group concept (e.g., men) with a given attribute concept (e.g., STEM). An important principle of this theory is that the association between two (initially) unlinked concepts (e.g., women and STEM) can be created and reinforced if these concepts share a common association with a third concept (e.g., the self).

We used this framework's rationale to make predictions regarding implicit gender-STEM stereotypes in our samples. Specifically, STEM women should hold associations between the self and women, but also between the self and STEM. Because women and STEM are both associated with the self, the association between women and STEM should be created and strengthened. If women and STEM are associated, then implicit stereotypes associating STEM more strongly with men than with women should be reduced, resulting in weak (or no) gender-STEM stereotypes. For non-STEM women, the self is not associated with STEM, and counter-stereotypic women-STEM associations are unlikely to be created. Consequently, non-STEM women should display implicit gender-STEM stereotypes. For engineering men, the self is associated with both men and STEM, and STEM is already connected to men (according to the gender stereotype). This should result in implicit gender-STEM stereotypes. For non-STEM men, the self may be less strongly associated to STEM than for STEM men. However, because the men-STEM association should not be under pressure or problematic for non-STEM men (as it is for STEM women), they are unlikely to develop strong counter-stereotypical associations, resulting in implicit gender-STEM stereotyping among them as well.

Consistent with Greenwald et al.'s (2002) framework, findings from a recent study conducted in the United States among female and male STEM students indicated that

STEM women held weaker implicit gender-math stereotypes than their male counterparts (Stout et al. 2011). These results can be contrasted with those from a study conducted among female and male undergraduates with various majors in the United States, which did not find gender differences in implicit gender-math stereotypes (Nosek et al. 2002). Differences in implicit stereotyping as a function of major were not investigated in that study. Together, these U.S. studies suggest that women and men in general hold the same implicit gender-stereotypic knowledge (which is consistent with the idea that stereotypes are shared within a given culture), but that if stereotypic associations conflict with—or are threatening to—self-knowledge (associating STEM with men when you are a woman in STEM), counter-stereotypic associations can be created. Because these studies did not simultaneously report findings for STEM and non-STEM women and men, our hypotheses derived from Greenwald et al.'s framework remain untested so far. We will test for this in the present research regarding implicit gender STEM-stereotypes specifically (i.e., we did not measure implicit self-STEM or self-group associations).

Although these previous studies have been conducted in the United States, we expected to find support for our hypotheses in French samples as well. Indeed, as long as negative stereotypes associating STEM disciplines and skills more with males than with females exist, Greenwald et al.'s (2002) framework - and its implications for implicit stereotypes—should be relevant and the present research should be useful for any country where these stereotypes are operating. Research conducted in France suggests that these gender stereotypes are known and that they can subtly influence performance (Guimond and Roussel 2001; Huguet and Régner 2007; Martinot et al. 2012). In addition, and in accordance with gender stereotypic expectations, percentages of women that can be found in engineering and humanities in France indicate an unequal gender distribution in these fields. For instance, 10 % of the engineering students in electronics, 11 % of those in computer science, 8 % of those in mechanical engineering, and 31 % of those in chemical engineering are women (French Association of Female Engineers 2006). Conversely, women represent 70 % of the humanities and social sciences students (Ministry of National Education, Youth, and Community Life 2011).

Given that gender-STEM stereotypes exist in France, but that STEM women are likely to create counter-stereotypical associations (Greenwald et al. 2002), we will test whether STEM women will display lower levels of implicit gender-STEM stereotypes as compared to non-STEM women, STEM men, and non-STEM men. In study 1, we will focus on implicit gender-math stereotypes. In study 2, we examined gender-reasoning stereotypes. This change was made because of generalizability concerns and because reasoning is not solely a hallmark of math ability, but of STEM disciplines more generally (Pronin et al. 2004). Because the engineering schools from which our samples were drawn emphasize the importance of a multidisciplinary science and technology training (Aerospace Institution of Higher Education 2009), reasoning and being rational should be particularly important for these students (beyond mere mathematical skills) and counter-stereotypical gender-reasoning associations likely to be created among female engineering students.

Implicit Gender-STEM Stereotypes and Achievement as a Function of Major

Regarding the implicit gender stereotype/performance relation, Nosek et al.'s (2002) research has shown that for U.S. female undergraduates, the stronger their implicit gender-math stereotypes, the weaker their liking for, the lower their identification with, and the lower their performance in math. The reverse was true for male undergraduates, for whom implicit gender-math stereotypes were positively related to math identification and performance. Another study, conducted among female psychology undergraduates in the United States, showed that even when the math test was not explicitly introduced as measuring math ability, implicit gender-math stereotypes negatively impacted women's performance (Kiefer and Sekaquaptewa 2007a). Also, Steffens and Jelenec (2011) found, in a German sample of female and male adolescents and university students, that stronger implicit gender-math stereotypes were associated with lower math self-concept and performance for women, but that this relation was positive for men. Finally, research conducted by Steffens et al. (2010) among German children and adolescents demonstrated that implicit gender-math stereotypes systematically predicted math-related outcomes among girls, but less consistently among boys.

Together, these U.S. and German findings show a negative relation between implicit gender-STEM stereotypes and achievement-related outcomes in these domains for women, and a sometimes positive and sometimes null relation for men. Refining these previous findings, we argue that, for women, the implicit stereotype/performance relation should vary as a function of major. Indeed, research on stereotype threat suggests that stereotypes are most likely to influence performance if they are accessible in the situation (Kiefer and Sekaquaptewa 2007a; C. M. Steele 1997). If gender-STEM stereotypes are weaker to begin with—as is expected to be the case for STEM women—these stereotypes are less likely to influence performance and the implicit gender stereotype/performance relation should be weak or absent. On the contrary, for non-STEM women, implicit gender-STEM stereotypes can be expected to be accessible in testing situations and to negatively influence performance. This would result, for non-STEM women, in a negative implicit stereotype/performance relation.

For men, stereotype threat research suggests that the effects of negative gender stereotypes on performance are not very pervasive, unless the stereotype is explicitly mentioned in the instructions (e.g., stating that the study is examining differences among women and men; Seibt and Förster 2004). In the present research, instructions never explicitly highlighted gender stereotypes or stereotypic expectations because mentioning such differences is rather unusual in real-life settings. Consequently, we expected the implicit gender stereotype/performance relation to be weak for men. To summarize, we expected to find a more negative implicit gender-STEM/performance relation for non-STEM women, as compared to STEM women, STEM men, and non-STEM men. To assess math performance, we relied on reported math grades (as in Nosek et al. 2002) and implicit stereotypes were assessed with two French versions of the Implicit Association Test (IAT; Greenwald et al. 1998): One assessing implicit gender-math stereotypes (study 1) and one (newly created) assessing implicit gender-reasoning stereotypes (study 2).

Characteristics of the Present Research's Samples

Why is a sample of French female engineering students appropriate to examine implicit gender stereotypes among STEM women? First, in the French education system, students who get enrolled in engineering schools are only those who obtained the highest grades in math and physics during high school (Marry 2004; Ministry of National Education and Ministry of Higher Education and Research 2006). Based on their high school grades, these students were subsequently allowed to attend preparatory schools during two or three years. The preparatory schools provide an intensive preparation for the competitive national examination, which, if successfully passed, provides access to engineering schools. These intensive preparation years are focused on high-level mathematics and physics. Those who finally get into the engineering schools are faced with a very difficult curriculum, which generally lasts three years. Second, because of the selectivity of the preparatory schools, the competitive national examination, and the attractive jobs and salaries waiting for them once they are graduated (National Council of French Engineers and Scientists 2007), students who get enrolled in French engineering schools rarely drop out. Consequently, French female engineering students can be unambiguously identified as women who are and will remain in STEM, and among whom hypotheses regarding STEM women's implicit gender-STEM stereotypes could be tested.

Contrary to the engineering schools, French universities (as is the case in some other European countries such as Italy; see Darnon et al. 2009) are less selective: To enter university, students are only required to have passed the high school exit exam (Baccalauréat; Darnon et al. 2009). In other words, every high school student who gets a sufficient mean grade on the exit exam (in France, 10 on a scale ranging from 0 to 20) can enter university. Furthermore, university students can choose their academic domain immediately after their first fall semester. Students who do not strongly identify with STEM disciplines can focus exclusively on non-STEM disciplines until graduation. As a consequence, many students enter university every year and choose to focus exclusively on humanities. For these students, there is no major/minor system: They are graduating in their discipline and only in their discipline (for convenience, we will occasionally refer to STEM versus non-STEM majors when describing the present research samples). Therefore, French humanities students can clearly be identified as non-STEM students and are a representative sample to examine gender-STEM stereotypes among non-STEM students.

At this point, it should be noticed that our predictions regarding engineering women's implicit stereotypes are framed in terms of a current-context approach: Evolving in STEM environments helps women to create counter-stereotypic associations and to hold weak implicit gender-STEM stereotypes. In turn, weaker gender-STEM stereotypes should support STEM achievement. However, the dynamics of female engineering students' STEM stereotypes and achievement may be less straightforward, and more bidirectional: Given that these women entered engineering schools because they were highly proficient in STEM disciplines, it is possible that their high achievement was fostered by weak implicit gender stereotypes to begin with. Because the present research focuses on women who are already enrolled in engineering schools, our reasoning relies on this context as a starting point. This does not imply that weak implicit gender stereotypes were not already operating prior to enrollment. Simply, the present studies were not designed to examine these earlier dynamics. We will return to this issue in the General discussion section.

Summary of Hypotheses

Based on the arguments presented above, we make the following hypotheses regarding study 1:

Hypothesis 1: French female engineering students hold weaker implicit gender-math stereotypes than female humanities, male engineering, and male humanities students.

We also make the following hypotheses regarding study 2:

Hypothesis 2: French female engineering students hold weaker implicit gender-reasoning stereotypes than female humanities, male engineering, and male humanities students.

Hypothesis 3. Implicit gender-reasoning stereotypes are more strongly (and negatively) related to math grades for female humanities students as compared to female engineering, male engineering, and male humanities students.

Study 1

Method

Participants

Participants were 27 aerospace engineering students (14 male and 13 female, M_{age}=21 years, SD_{age}=.92) attending a selective French engineering school and 28 humanities undergraduates (14 male and 14 female, M_{age}=22 years, SD_{age}=2.20) from a less selective French university. All participants volunteered to take part in a study on “reaction times and judgments”. They were not remunerated for their participation.

Procedure and Measures

Participants were met in small groups by a female experimenter at their school or university and were subsequently conducted to a quiet room. The gender-math IAT was adapted from Nosek et al. (2002; see the Appendix for the original items in French and their English translation) and was performed on a computer. The IAT is a reaction time measure in which participants categorize words in four categories such as, for example, *male, female, mathematics*, and *language* in the case of a gender-math IAT (Nosek et al. 2002). Participants are asked to respond rapidly with a right-hand key press to items representing male (he, boy) and math (algebra, geometry), and with a left-hand key press to items representing female (she, girl) and language (grammar, words). These trials are typically referred to as the (stereotype) congruent trials, and participants perform a practice block (20 items) and a test block (40 items) of these congruent trials. Participants then perform a second task (randomly completed before or after the first one) in which the key assignment for one of the pairs is switched (such that male and language share a response key, and, likewise, female and mathematics share a response key). As for the congruent trials, participants perform a practice block (20 items) and a test block (40 items) of the incongruent trials. The IAT produces measures derived from the response latencies for these congruent and incongruent blocks (the interested reader can also take an IAT on the demonstration website dedicated to this test: https://implicit.harvard.edu/implicit/). The IAT effect is interpreted in terms of associative strength by assuming that individuals respond more rapidly when the concept and the attribute mapped onto the same response key are strongly associated (male and mathematics) than when they are weakly associated (female and mathematics).

D-scores were created for each IAT. *D*-scores represent the difference in mean response latency between the gender-stereotype incongruent and congruent tasks divided by the participant’s latency standard deviation on the two tasks (Greenwald et al. 2003). The advantage of *D*-scores as compared to other scoring methods is that they reduce the contamination of the IAT measure by overall differences in response speed (Greenwald et al. 2003). This is important because our studies were conducted on two different samples (engineering and humanities students). Nevertheless, interpretation of IAT scores remains unchanged, with positive scores indicating stronger implicit gender stereotyping (see Table 1 for means and standard deviations). To test for internal consistency of our gender-math IAT, we followed recommendations made by Schnabel et al. (2007). We computed split-half reliabilities over the difference scores of the congruent and incongruent practice and test blocks. The internal consistency correlation, $r(53)=.84$, $p<.001$, was higher than the values reported by Greenwald et al. (2003) for their web-based gender IAT (which varied between .55 and .60).

Results and Discussion

Description of the Samples

Characteristics of the samples are reported in Table 1. Results of a 2(Gender: female, male) x 2(Sample type: engineering, humanities) analysis of variance (ANOVA) performed on participants’ age showed that engineering

Table 1 Mean implicit gender-math and gender-reasoning stereotyping, age and math grades (with standard deviations) as a function of gender (female, male) and sample type (engineering students, humanities students)

	Engineering students		Humanities students		Total
	Female M(SD)	Male M(SD)	Female M(SD)	Male M(SD)	M(SD)
Study 1					
Age	20.92(.95) [a]	21.07(.92) [a]	21.79(2.04) [b]	22.43(2.38) [b]	21.56(1.77)
Implicit gender-math stereotyping	−.13(.68) [a]	.37(.36) [b]*	.41(.59) [b]*	.27(.62) [b]	.24(.60)*
Study 2					
Age	21.34(1.92) [a]	20.88(1.11) [a]	20.95(2.03) [a]	22.54(2.99) [b]	21.35(2.10)
Implicit gender-reasoning stereotyping	.38(.32) [a]*	.55(.33) [b]*	.46(.32) [b] *	.52(.31) [b] *	.48(.32)*
Math grades (Min=0, Max=20)	15.79(2.84) [a]	16.19(2.88) [a]	11.96(4.15) [b]	12.79(4.16) [b]	14.56(3.86)

Within a row, means with different subscripts differ significantly at $p<.05$. Age corresponds to participants' age at the time of the study. Implicit gender-math and gender-reasoning stereotyping correspond to participants' *D*-scores (i.e., the difference in mean response latency between the gender-stereotype incongruent and congruent tasks divided by the participant's latency standard deviation on the two tasks) on the gender-math and gender-reasoning Implicit Association Tests, respectively. In Study 1, observed *D*-scores ranged from −1.13 to 1.14, and in Study 2 from −.39 to 1.39. Math grades represent participants' math grade at the French Baccalauréat (i.e., the high school exit exam)

* Significantly greater than 0 at $p<.05$

students were younger than humanities students, $F(1, 51)=5.77$, $p<.03$. No other main or interaction effects were found. In addition, one sample *t*-tests against 0 indicated that the gender-math IAT effect was significant for female humanities and male engineering students, but not for female engineering and male humanities students. Thus, while female humanities and male engineering students held implicit gender-math stereotypes, this was not so for female engineering and male humanities students. It should be noted, however, that the gender-math IAT effect for the whole sample was significantly greater than 0 ($M=.24$, $SD=.60$), $t(54)=2.93$, $p<.01$, although IAT scores were close in magnitude to those of the male humanities students ($M=.27$, $SD=.62$), $t(13)=1.64$, $p=.12$. Therefore, lack of power may account for the non-significant IAT effect among male humanities students.

Implicit Gender-Math Stereotypes

Hypothesis 1 stated that French female engineering students hold weaker implicit gender-math stereotypes than female humanities, male engineering, and male humanities students. Because this hypothesis made clear predictions for each group, we tested this hypothesis with a one-way analysis of variance (ANOVA) and a set of Helmert contrasts. In these types of analyses, only one of these contrasts - the contrast of interest - is theoretically relevant. The other contrasts are merely added to use all degrees of freedom, should be non-significant, and are theoretically irrelevant (see, for instance, Brauer and McClelland 2005; Judd and McClelland 1989; Rosenthal and Rosnow 1985 for further details regarding the use of contrasts). Here, the first contrast - the contrast of interest - tested Hypothesis 1, that is, whether female engineering students held weaker implicit gender-math stereotypes than female humanities students, and than male engineering and male humanities students (−3, +1, +1, +1, respectively). The second contrast - which must be non-significant - tested whether engineering men held weaker implicit stereotypes than humanities women, and men (0, −2, +1, +1, respectively). The third contrast - which should also be non-significant - tested whether humanities women held weaker implicit stereotypes than humanities men (0, 0, −1, +1). As expected, the first contrast was significant, indicating that engineering women ($M=-.13$, $SD=.68$) held weaker implicit stereotypes than humanities women ($M=.41$, $SD=.59$), and than engineering ($M=.37$, $SD=.36$) and humanities men ($M=.27$, $SD=.62$), $t(17)=2.30$, $p<.05$. The second contrast was non-significant, indicating that there were no differences between humanities women, engineering men, and humanities men's implicit gender-math stereotypes, $t(38)=-.19$, *ns*. The third contrast indicated that there were no differences in implicit stereotyping between humanities women and men, $t(26)=-0.60$, *ns*. Levene's test indicated unequal variances, $F(3, 51)=3.55$, $p<.03$, so degrees of freedom were adjusted. Together, results from the contrast analyses provided support for Hypothesis 1. It can be noted that results of a more classical 2 (Gender: female, male) x 2(Sample type: engineering, humanities) ANOVA showed similar results, $F(1, 51)=4.14$, $p<.05$. However, because ANOVA does not allow for a comparison between one group and the three others, we believe that contrast analyses provide a more stringent test of our hypothesis.

Results of study 1 showed, as expected, that French female engineering students held weaker implicit gender-math stereotypes than female humanities students, but also than male engineering and male humanities students. Although study 1 provides support for the hypothesis that female STEM students hold weaker implicit gender-STEM stereotypes than other groups of students, this study did not include a performance indicator, making it impossible to test for an implicit gender stereotype/performance relation. In addition, the study's sample size was small and the implicit stereotype measure focused on math, while we have reasons to believe that other STEM-related skills, such as reasoning, are important for French engineering students (Aerospace Institution of Higher Education 2009).

Given these limitations, we conducted a second study among a larger sample and focused on another implicit gender stereotype, namely, the one assuming that women are less good at logical reasoning - and are thus less rational - than men (Davies et al. 2002). Reasoning was chosen because it is assumed to be a hallmark of math ability and of STEM disciplines more generally (Pronin et al. 2004). In addition, rationality can be opposed to emotionality (Nosek 2005; Pronin et al. 2004), which is important because the IAT requires contrasting categories. Finally, we asked participants to report their math grades at the Baccalauréat, and these grades were used as a proxy for actual math grades. This has been done in previous research because self-reported grades are generally highly related to actual grades (Nosek et al. 2002).

Study 2

Method

Participants

Participants were 117 aerospace and mechanical engineering students (53 female and 64 male, M_{age}=21 years, SD_{age}=1.54) attending a selective French engineering school and 84 humanities undergraduates (43 female and 41 male, M_{age}=22 years, SD_{age}=2.65) from a less selective French university. Five additional humanities students (one female, four male) were tested but not included in the analyses because they were older than 30 years, and as such could not be considered as young undergraduates. Data were collected as part of a larger study on reasoning but, as in study 1, the IAT was introduced as a task on "reaction times and judgments" and typical IAT instructions were further used. Participants were paid 5 euros for their participation.

Procedure and Measures

The procedure was the same as in study 1, except that participants were tested in individual cubicles by a female experimenter and that the IAT was designed to measure implicit gender-reasoning stereotypes. The IAT's four categories were *masculine*, *feminine*, *rationality*, and *emotionality*. The internal consistency correlation of this newly created IAT, $r(199)=.59$, $p<.001$, was similar to the values reported by Greenwald et al. (2003) for their web-based gender IAT.

The items used for the rationality and emotionality categories were pre-tested among another sample of engineering students (10 males, 10 females) who rated the gender stereotypicality of the rationality-related attributes used by Heilman et al. (1995; see the Appendix for the items). As indicated by this pre-test, items relating to rationality (e.g., being rational, objective) were perceived as more stereotypical of men than of women, while the reverse was true for items associated with emotionality (e.g., being sensitive, emotional).

At the end of study 2, participants reported demographic data, including their gender and their math grade at the Baccalauréat (two female and five male humanities students did not report this grade and were therefore excluded from the analyses involving math grades). Participants were thanked, paid, and debriefed.

Results and Discussion

Description of the Samples

Results of a 2(Gender: female, male) x 2(Sample type: engineering, humanities) ANOVA performed on math grades showed that engineering students (M=16.01, SD=2.86) had higher math grades than humanities students (M=12.35, SD=4.15), $F(1, 190)=51.05$, $p<.001$, while there was no significant effect of gender, either alone or in interaction with sample type. This finding is consistent with the fact that engineering students are recruited in engineering schools thanks to their math proficiency. Regarding age, results of the ANOVA revealed that engineering students (M=21.09, SD=1.54) were younger than humanities students (M=21.73, SD=2.65), $F(1, 197)=4.87$, $p<.03$, and female students (M=21.17, SD=1.97) were younger than male students (M=21.52, SD=2.20), $F(1, 197)=3.75$, $p=.05$. These main effects were qualified by a two-way gender by sample type interaction effect, $F(1, 197)=12.56$, $p<.001$, indicating that male humanities students were older than male engineering students, $F(1, 197)=16.97$, $p<.001$, and than female humanities students, $F(1, 197)=12.94$, $p<.001$. In addition, as can be seen in Table 1, all mean IAT scores were significantly different from 0, indicating that for each group, the IAT effect was significant and positive. Thus, each group—including female engineering students—held implicit gender-reasoning stereotypes.

Implicit Gender-Reasoning Stereotypes and their Relation with Math Grades

To test for Hypothesis 2, we used the same set of Helmert contrasts as in study 1. The first contrast—the contrast of interest—tested Hypothesis 2, that is, whether female engineering students held weaker implicit gender-reasoning stereotypes than female humanities, male engineering and male humanities students. The second and third contrasts were, again, theoretically irrelevant and were expected to be non-significant. Results regarding contrast 1 indicated, as expected, that engineering women (M=.38, SD=.32) held weaker implicit gender-reasoning stereotypes than humanities women (M=.46, SD=.32) and men (M=.52, SD=.31), and than engineering men (M=.55, SD=.33), $t(197)=2.45$, $p<.02$. The second contrast showed that there were no differences between engineering men, humanities women, and humanities men's implicit gender-reasoning stereotypes, $t(197)=-1.12$, *ns*. The third contrast, which compared humanities women and men, was non-significant, $t(197)=0.78$, *ns*. Hypothesis 2 was thus supported.

Hypothesis 3 stated that implicit gender-reasoning stereotypes would be more strongly (and negatively) related to math grades for female humanities students as compared to female engineering, male engineering, and male humanities students. We computed correlation coefficients for each group (Table 2). Implicit stereotyping was indeed negatively related to math grades for female humanities students, $r(39)=-.45$, $p<.01$, but not for female engineering, $r(51)=.06$, *ns*, male engineering, $r(62)=.19$, *ns*, or male humanities students, $r(34)=.07$, *ns*. Using Fisher's r to Z transformation, comparisons between correlation coefficients showed that implicit gender-reasoning stereotypes were more strongly related to math grades for female humanities students as compared to female engineering students ($p<.01$), male engineering ($p<.001$), and male humanities students ($p<.02$). Correlations coefficients for the other groups did not differ (all $ps>.49$). Hypothesis 3 was supported.

Findings from study 2 replicated and extended those of study 1, with a larger sample and another implicit gender stereotype. Precisely, female engineering students' implicit gender-reasoning stereotypes were weaker than those of the three other groups, although their mean IAT scores were larger than those in study 1. This difference will be discussed in the General discussion section. Of importance, results from study 2 show that implicit gender stereotypes are not necessarily negatively associated to math performance for all women. Indeed, while implicit gender-reasoning stereotyping was negatively related to math grades for female humanities students, this was not the case for female engineering, male engineering, and male humanities students.

Table 2 Intercorrelations between implicit gender-reasoning stereotyping and math grades as a function of gender (female, male) and sample type (engineering students, humanities students)

	Female students		Male students	
	1	2	1	2
1. Implicit gender-reasoning stereotyping	–	−.45**	–	.07
2. Math grades	.06	–	.19	–

Correlations for engineering students are displayed below the diagonal and those for humanities students above the diagonal. Implicit gender-reasoning stereotyping corresponds to participants' D-score (i.e., the difference in mean response latency between the gender-stereotype incongruent and congruent tasks divided by the participant's latency standard deviation on the two tasks) on the gender-reasoning Implicit Association Test. Math grades represent participants' math grade at the French Baccalauréat (i.e., the high school exit exam)

** $p<.01$

General Discussion

In spite of the many barriers facing women's success in counter-stereotypic, masculine disciplines such as STEM, some women are successful in these fields. The present studies' aim was to examine whether STEM women would hold weaker implicit gender-STEM stereotypes than non-STEM women. Two studies provided evidence that French female engineering students held weaker implicit gender-math and gender-reasoning stereotypes than female humanities, male engineering and male humanities students. Consequently, if at an implicit level, engineering women hold weaker gender-STEM stereotypes than most other women, these stereotypes are also less likely to be negatively related to their STEM achievement.

In support of this explanation, and consistent with expectations derived from Greenwald et al.'s (2002) Unified Theory regarding implicit stereotyping, we found that implicit gender stereotyping was not related to math performance for female engineering students, but was negatively related to math performance for female humanities students. This finding complements those from U.S. and German studies showing a negative relation between implicit gender-STEM stereotypes and achievement-related outcomes in these domains for women in general (Kiefer and Sekaquaptewa 2007a; Nosek et al. 2002; Steffens et al. 2010). Our results refine these previous findings and suggest that implicit gender stereotypes are not necessarily negatively associated to math performance for all women. Interestingly, our results also provide a possible explanation for an intriguing finding by Crisp et al. (2009). These authors demonstrated that English female engineering students did not display reduced math performance when confronted with a threatening gender comparison, while female psychology students displayed the typical stereotype threat effect on their math performance. Given that female engineering students' implicit gender-STEM stereotypes were not related to their math performance in our research, this might explain why they did not suffer from a threatening comparison in the Crisp et al. (2009) study.

In addition to weak implicit gender-STEM stereotyping, female engineering students may also have developed strong (implicit) self-STEM associations, a possibility in accordance with Unified Theory (Greenwald et al. 2002). Although implicit self-STEM associations were not investigated in the present research, our findings regarding implicit gender-STEM stereotypes suggest that this may have been the case. Assuming strong implicit self-STEM associations were present among STEM women, it can be expected that even when negative gender stereotypes are salient to some extent, STEM women can counteract stereotypes' biasing influence on performance by valuing the self in these fields. And indeed, U.S. and French research indicates that an efficient means to counteract stereotype threat is to affirm one's self-concept in valued domains (Croizet et al. 2001; Martens et al. 2006). Examining whether such self-affirmation strategies are (implicitly) implemented by female engineering students may be an important avenue for future research.

While the present research shows that French female engineering students hold weaker implicit gender-STEM stereotypes than other groups of students, it does not allow drawing definite conclusions about why these stereotypes were weaker to begin with or about the causal link between implicit gender-STEM stereotyping and STEM achievement. As highlighted in the Introduction section, the present research focused on women who were already enrolled in engineering schools. We therefore used this context as a starting point and developed our predictions regarding implicit stereotypes stemming from Unified Theory within this context. Also, in line with this framework and the development of counter-stereotypic women-STEM associations, it can be assumed that because engineering women are themselves counter-stereotypic exemplars, the salience of their own success reduces implicit gender-STEM stereotypes. This explanation finds support in studies investigating the influence of counter-stereotypic exemplars on implicit stereotyping (Dasgupta and Asgari 2004; Stout et al. 2011). These studies, conducted among U.S. undergraduates, have shown that when women are confronted with salient and successful counter-stereotypic exemplars from their in-group, implicit stereotyping is reduced.

The focus on a current-context explanation does not imply that we simply ignore that other processes may have been operating prior to enrollment in the engineering schools. For instance, it is possible that French female engineering students benefited from an early counter-stereotypic family socialization environment. Indeed, Marry (2004) reported, on the basis of case studies conducted among French female engineers, that one thing these women had in common was a mother with a university degree in STEM. In turn, given that parents' gender-related beliefs are assumed to influence their children's self-perceptions of ability and interest in a given ability domain (Eccles et al. 1990; Jacobs 1991; Tenenbaum and Leaper 2003; Tiedemann 2000), it is possible that these women benefited from their mothers' non-biased (or less biased) beliefs. This should have fostered their math achievement and allowed them to be enrolled in engineering schools. However, the present studies were not designed to assess these socialization dynamics and we did not have access to information regarding students' socio-economic background. Therefore, we did not systematically investigate this complementary explanation, but doing so would be important for future research.

On a related note, it can be argued that we did not examine the possible influence of variables such as general cognitive ability, achievement goals or self-esteem, although female engineering and humanities students may differ on these dimensions (beyond mere differences in academic field and type of educational institution). Also, given the selectivity of the engineering schools, female (and male) engineering students may represent a high-status group, making it possible that status, and not academic domain per se, accounted for our findings. Although an examination of these variables' influence is certainly important, we do not believe that these variables were of determining influence in our studies. First, male engineering and male humanities students were just as likely as female engineering and female humanities students to differ on these dimensions. In spite of these possible variations, we did not find notable differences between male engineering and male humanities students' implicit stereotypes or regarding stereotypes' relation to math performance. Second, assuming that female engineering students' high-status had played a determining role, they would have held strong - and not weak - implicit gender stereotypes. Indeed, according to an abundant literature on system justification, high-status group members, as they benefit from the existing system, are particularly likely to perpetuate (implicit) stereotypes and attitudes serving the status quo (Jost and Hunyady 2005; Jost et al. 2004; see also Richeson and Ambady 2001, 2003, for the influence of power on implicit attitudes).

Together, the present findings are encouraging for women in STEM, especially because male engineering students held strong implicit gender stereotypes. Implicit cognitions, as measured by the IAT, are related to discriminatory behavior in the United States (McConnell and Leibold 2001; Rudman and Ashmore 2007). Moreover, STEM women in the United States feel more discriminated against than non-STEM women (J. Steele et al. 2002). In spite of these potential additional obstacles, engineering women in our studies are remaining in STEM and are very likely to pursue a professional career in these fields, not the least because attractive jobs and salaries are waiting for them once they have graduated (National Council of French Engineers and Scientists 2007). However, given engineering men's strong implicit gender stereotyping, which might be related to discrimination, it seems worthwhile to design interventions that could increase women's sense of belonging in STEM. As our results suggest, interventions should not solely target women, but also men. Future research is needed to examine, in France and in other countries where women are underrepresented in STEM, whether STEM men's implicit gender stereotypes are related to prejudice and discrimination.

Finally, although female engineering students in our studies held weaker implicit stereotypes than the other groups, their mean IAT scores differed for the gender-math and the gender-reasoning IATs. Findings for the gender-math IAT indicated that female engineering students did not hold implicit gender-math stereotypes (Greenwald et al. 2006; but see Blanton and Jaccard 2006 for a discussion on the metric meaningfulness of the IAT's zero value), whereas those for the gender-reasoning IAT showed a significant IAT effect that is, the presence of implicit gender-reasoning stereotyping among engineering women. One explanation for this finding might be related to the domain. Math, on the one hand, is a well-defined academic discipline in which engineering women had to demonstrate competence. Therefore, they might be used to negating stereotypic associations related to women and math. Repeated negation, in turn, might have contributed to specifically reducing stereotypic associations regarding the math domain (see Kawakami et al. 2000 for the effects of training in the negation of stereotypic associations in Dutch samples). Reasoning, on the other hand, is a more general, super ordinate domain, which does not correspond to a specific academic discipline. Consequently, although engineering women certainly reason every day, they might be less used to negating stereotypes related to the reasoning domain *per se*, resulting in stronger implicit associations as compared to math.

An alternative explanation is related to the use of different contrasting categories in the gender-math and gender-reasoning IATs. In the former, math was contrasted with language, as has been done in Nosek et al. (2002). In the latter, rationality was contrasted with emotionality. The null finding for the gender-math IAT among engineering women can be interpreted as an equally strong association between female and the math and language concepts. The presence of implicit gender-reasoning stereotyping suggests that even these women—albeit to a lesser extent than any of the other groups—associate female more with emotionality than with rationality. Relatedly, emotionality may have been perceived as more positive than rationality and U.S. research suggests that "people possess implicit gender stereotypes in self-favorable form because of the tendency to associate self with desirable traits" (Rudman et al. 2001, p. 1164). If female engineering students perceived emotionality as something positive, then a strong implicit emotionality-women association may have masked a rather weak implicit rationality-men association. Finally, procedural differences, such as the different sample sizes in study 1 and 2, the fact that IATs were completed in groups (study 1) versus individual (study 2) sessions, or that general instructions in study 2 put the focus on reasoning (which may have increased stereotype accessibility) may also account for the observed differences. Future research should investigate these alternative possibilities, for instance by examining more systematically counter-stereotypic women's implicit gender stereotypes in different domains, as well as the potential influence of different contrasting categories.

In sum, our findings suggest that a specific characteristic of STEM women—and a possible explanation for their counter-stereotypic success—is their weaker implicit gender-STEM stereotyping as compared to more stereotypic individuals. Understanding such psycho-social determinants may be particularly valuable in contexts where a former Harvard University president stated that "in the special case of science and engineering, there are issues of intrinsic aptitude […] and those considerations are reinforced by what are in fact lesser factors involving socialization" (Summers 2005, para. 6).

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Appendix

Words used as stimuli on the gender-math (Study 1) and the gender-reasoning (Study 2) implicit association tests. The original stimuli (in French) are provided along with their English translation

Category					
Féminin/Feminine	Masculin/Masculine	Mathématiques/Mathematics	Lettres/Language	Rationalité/Rationality	Emotivité/Emotionality
fille/daughter	père/father	algèbre/algebra	Français/French	cohérent/consistent	émotif/emotional
féminin/feminine	grand-père/grandfather	formule/formula	grammaire/grammar	déduction/deduction	empathie/empathy
grand-mère/grandmother	homme/man	géométrie/geometry	mots/words	logique/logical	sentiments/feelings
mère/mother	masculin/masculine	équation/equation	phrase/sentence	objectif/objective	intuitif/intuitive
épouse/wife	fils/son	multiplier/multiply	adjectif/adjective	rationnel/rational	sensible/sensitive
femme/woman	oncle/uncle	nombres/numbers	verbes/verbs	raisonnement/reasoning	subjectif/subjective

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