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An implicit gender sex-science association in the general population and STEM faculty

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ABSTRACT

We investigated implicit associations between social categories *female* or *male* and the attributes *sex* or *science*. In six experiments, Implicit Association Tests (IATs) showed *female + sex/male + science* associations. The bias was observed (a) in both men and women; (b) in participants who reported sexual attraction to both females and males (greater for the former); (c) in members of the general population as well as among STEM faculty from the highest ranked U.S. STEM universities; (d) even when both gender categories were clearly presented as scientists, via photos and words, (e) using both the standard IAT and a single category variation; and (f) hardly at all on explicit measures in contrast to implicit measures. By introducing the attribute of sexuality, these studies bring to light a robust if unintended mental association of women as sexual beings. The automaticity and surprising generality of the effect suggests that this association may be an unintentional yet potent barrier to women's lower representation and success in STEM.

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Creating and sustaining a large and talented workforce in STEM (science, technology, engineering, and mathematics) is crucial for innovation, the economy, and the well-being of a nation. According to the 2012 report of the President's Council of Advisors on Science and Technology, the United States must increase the participation of talented scientists in STEM over the next decades to remain competitive and maintain global leadership (President's Council of Advisors on Science & Technology &, 2012).

Among the currently under-exploited resources in STEM workforce are women (Hill, Corbett, & St Rose, 2010), and this gender gap has been attributed to varied and interrelated factors. Research suggests that women's own lives and professional choices (Ceci & Williams, 2011; Williams &

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Ceci, 2015), as well as the presence of gender bias in perceptions and treatment of women in STEM may be responsible for their lower representation, success, and job satisfaction. Consistent with the latter hypothesis, several studies have shown that women face challenges in STEM, such as not receiving equal treatment in *hiring decisions* (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Reuben, Sapienza, & Zingales, 2014; Sheltzer & Smith, 2014), *funding allocation* (Bornmann, Mutz, & Daniel, 2007; Wenneras & Wold, 1997), *publishing* (Knobloch-Westerwick, Glynn, & Huge, 2013; Lortie et al., 2007; Sarsons, 2015), in *awards* and *recognitions* (Charlesworth & Banaji, 2019).

In a landmark study, Moss-Racusin et al. (2012) found that science faculty, both male and female, rated male resumes to be superior to identical female resumes. Moreover, Reuben et al. (2014) conducted a study in which participants were asked to select candidates for "a math task" from a pair of male-female candidates. The task actually involved simple arithmetic, and as expected, men and women performed equally well on the task on average. However, the study found that when no information about skill was provided, both male and female decision-makers were twice more likely to hire a man than a woman. Next, when participants were provided information about actual math performance, data showed that gender bias continued to persist (although it was attenuated). Importantly, the degree of correction was predicted by the perceiver's implicit gender-science bias such that those with higher implicit gender-science stereotypes were less likely to correct their choice based on actual evidence about ability. This finding—of an association between the strength of mental association and actual job selection—makes it imperative to test the strength of mental associations in a variety of attributes associated with gender.

For example, research has shown that the explanation for gender bias can be pinned to a perception of women as less *competent* (Moss-Racusin et al., 2012), *brilliant* (Bian, Leslie, & Cimpian, 2017, 2018; Jaxon, Lei, Shachnai, Chestnut, & Cimpian, 2019; Rivera & Tilcsik, 2019; Storage, Charlesworth, Banaji, & Cimpian, 2020), or lacking in the *intellectual talent* required for success in specific disciplines, such as mathematics (Leslie, Cimpian, Meyer, & Freeland, 2015). Additionally, data collected across 34 countries showed that the stronger the male = science stereotype, the greater the gender disparity (girls underperforming relative to boys) in a standardized 8th-grade math test (Nosek et al., 2009).

In this paper, we introduce a feature of gender beliefs that has been previously ignored, but directly relevant given the differences between men and women. A historically present association of "female" with the attribute of sex and sexuality provides us with the evidence necessary to undertake this test. Throughout documented history, women more than men, have

been perceived and represented as sexual objects (Archer, Iritani, Kimes, & Barrios, 1983; Bartky, 1990; Swim, Hyers, Cohen, & Ferguson, 2001; Szymanski, Moffitt, & Carr, 2011; Ward, 2003). Sexual objectification is defined as the practice of viewing and/or treating a person as an object (i.e., a thing) valued primarily for the physical and sexual attractiveness and for the use and pleasure of others (Fredrickson & Roberts, 1997). According to objectification theory, cultural practices of sexually objectifying women via public display of the female body are visible in many societies (Calogero, 2012; Fredrickson & Roberts, 1997) and include media portrayals of women that over-emphasize their bodies and sexual nature (Carrotte, Prichard, & Lim, 2017; Ghaznavi & Taylor, 2015; Kapidzic & Herring, 2015; Lamb & Koven, 2019; Tiggemann & Zaccardo, 2018; Ward, 2016).

This association between "female" and sex is also visible in studies showing differences in the cognitive representation of women and men: female bodies are recognized better when presented as sexual parts (versus whole bodies), whereas male bodies are recognized better when presented as whole bodies (versus sexual parts) (Gervais, Vescio, Förster, Maass, & Suitner, 2012). A recent study combining text mining and machine learning showed that people in academia portray and judge women compared to men using language that points to their physical and sexual appearance more so than their academic and professional roles (Wu, 2017).

Such evidence notwithstanding, it is surprising that in the dozens of studies conducted on gender bias in science, not a single one has explored the relative strength of association between male/female and the concepts of sex/science. The purpose of this research is to provide a first test of whether such an association exists and to explore its boundary conditions—including methodological aspects of the IAT—by presenting women and men as scientists and testing variations in their depictions by comparing the data from implicit measures to explicit reports, as well as observing features of the test taking sample—such as subject's gender, sexual orientation and expertise in STEM. Across six experiments we provide answers to these questions.

Overview

We conducted six experiments to test the presence of a female-sex/male-science association that may or may not be available to conscious awareness or conscious control but may be detected on a measure of implicit cognition. To this end, we examined whether an implicit female-sex/male-science association exists (a) in members of the general population (Experiment 1); (b) when methodological constraints of the IAT are

removed (Experiments 2 and 3); (c) when men and women are clearly represented as scientists via photos of individuals in lab coats and using scientific equipment (Experiment 4) as well as words that clearly denote STEM professions such as chemist, physicist, etc. (Experiment 5); (d) among members of STEM faculty from the highest-ranked STEM universities in the U.S. (Experiment 6); and (e) in both men and/or women, and in those who report being sexually attracted to men and/or women (meta-analysis of Experiments 1–6). Thus, each experiment offers a particular combination of ways to represent gender categories, IAT variations, and samples. If the concepts science and sex are equally associated to male and female, the IAT score should reveal neutrality (a score close to zero); if on the other hand, the concept science or sex is more associated to male or female, the IAT score should reveal a deviation from zero in one or another direction.

Experiment 1

No previous data exist showing an implicit association of gender categories with sex versus science. As such, the purpose of Experiment 1 was to perform a first test of whether an implicit gender sex-science belief exists today in our society and to compare this result to the explicit expression of the same stereotype on an explicit measure to examine the association between the two.

Methods

Participants

345 participants (M_{age}= 36.09, SD_{age}=15.20, 69.6% women, 74.2% U.S. citizens/residents, 68.4% Whites) were recruited at the Project Implicit website (https://implicit.harvard.edu; for a detailed description of the recruitment process, see Supporting Information). Conduct of Experiment 1 and all other experiments reported in this paper were approved by the Harvard University's institutional review board.

Procedure

After completing a few relevant demographic items (i.e., gender, sexual attraction, race, age, and nationality), each participant completed two measures: (1) an Implicit Association Test (IAT) to measure the strength of association between the social categories *male* and *female* and the attributes *sex* and *science* (implicit stereotype), (2) self-reported responses to measure explicit associations between the same categories and attributes (explicit stereotype). Because the primary interest was in the processes of implicit cognition, the order of these measures was fixed. Participants were

Table 1. Implicit and explicit scores by experiment.

	Sessions	Implicit				Explicit				Implicit and Explicit Correlation
Experiment	*N*	*N*	*M*	*SD*	Cohen's d	*N*	*M*	*SD*	Cohen's d	*r*
Exp. 1 (IAT)	345	213	0.38**	0.41	0.93	206	−0.06	0.74	−0.08	−0.05
Exp. 2 Female (SC-IAT)	226	154	0.23*	0.30	0.77	151	−0.11	1.66	−0.07	−0.07
Exp. 2 Male (SC-IAT)	245	153	−0.04	0.30	−0.13	153	−0.01	1.54	−0.01	0.09
Exp. 3 Sex (SC-IAT)	240	154	0.12*	0.33	0.36	156	0.12	1.12	0.11	0.05
Exp. 3 Science (SC-IAT)	214	153	0.04	0.33	0.12	154	−0.28*	0.84	−0.33	−0.05
Exp. 4 (IAT)	795	773	0.30*	0.39	0.77	778	0.13*	0.42	0.31	0.10*
Exp. 5 (IAT)	293	157	0.20*	0.43	0.47	154	0.12*	0.58	0.21	0.23*
Exp. 6 (IAT)	156	154	0.39*	0.41	0.95	151	0.22	0.86	0.26	0.02

*$p < 0.01$; **$p < 0.05$.

Implicit scores could range from +2 to −2, whereas explicit scores could range from +3 to −3. Positive scores indicated the presence of sex bias associations against women. Zero indicated no relative association. Sessions refer to the number of participants who completed at least one of the measures used in each experiment (i.e., IAT/SC-IAT and explicit items). Data collection stopped after each experiment reached a set number of participants that completed both measures: 200 in Experiment 1 and 150 in all the subsequent experiments (in Experiment 4, more participants were collected due to a coding glitch that failed to stop data collection).

debriefed about the purpose of the study and provided with additional background about research on implicit social cognition. The experimental session lasted about 10 minutes on average.

Materials

Measure of implicit gender sex-science beliefs

Implicit associations were measured by means of an Implicit Association Test (IAT) (Greenwald, McGhee, & Schwartz, 1998). The IAT relies on measures of response latencies and classification errors as reflections of the strength of implicit associations between categories (e.g., male and female) and attributes (e.g., career and family) (Greenwald & Banaji, 1995). Direct experience with the method is available at https://implicit.harvard.edu/implicit/takeatest.html. For Experiment 1, the IAT was constructed to measure the associations between the categories *male* and *female* and the attributes *sex* and *science*. Generic terms (e.g., woman, female, man, male) were used as stimuli for the social categories *female* and *male*, whereas different STEM disciplines (e.g., physics, engineering, math) and words referring to the act of sex and would include both men and women equally (e.g., kiss, intercourse, intimacy) were used as attributes denoting *science* and *sex*. All labels and complete stimuli used are available in Table S1 (Supporting Information).

The IAT followed the standard procedure described by Nosek, Greenwald, and Banaji (2005). Participants practiced sorting the categories *male* and *female* using two computer keys and then practiced sorting the attributes *science* and *sex* using the same two keys. In the critical blocks, participants were given all four items and sorted one pairing first (e.g., *female* + *sex/male* + *science*) and then the opposite pairing (e.g.,

Table 2. Regression Models Predicting the IAT Scores.

				IAT scores		
Model	df	Parameter	R^2	b^+	SE^+	t
M1	1278	Intercept	0.002	0.298	0.014	20.735
		Male[a]		0.040	0.023	1.722
M2	332	Intercept	0.023	0.334	0.030	11.087
		Attracted to Women[b]		*0.125*	*0.045*	*2.781**

[+]Unstandardized coefficients.
[a]Reference to Female.
[b]Reference to attracted to Men.
*$p < 0.01$.

female + science/male + sex). In between the two critical blocks, participants re-practiced the switched category. The order of the critical blocks was counterbalanced across subjects.

Measure of explicit gender sex-science beliefs

Explicit beliefs were assessed by means of four self-reported items assessing explicit associations between the gender categories *male* and *female* and attributes *sex* and *science*. To create the closest parallel between explicit and implicit measures, participants were asked to rate the extent to which they associated each gender category (e.g., *male* and *female*) to the attributes *science* and *sex* (e.g., "Please rate the extent to which you associate the category *female* to the concept *sex*. That is, to what extent does the category evoke feelings of things like sex, intercourse, kiss, and intimacy."). Responses were obtained on a 4-point scale ranging from 0 to 3 (e.g., 0 "Not at all sex" and 3 "Strongly sex"). All explicit items are available in Table S2, Supporting Information.

Results and discussion

Implicit gender sex-science beliefs

IAT scores were computed according to the algorithm described by Greenwald, Nosek, and Banaji (2003). That is, we divided the difference in mean response between the two IAT conditions (i.e., incongruent and congruent) by the participant's latency standard deviation inclusive of the two conditions. Responses faster than 350 ms and slower than 10,000 ms were removed, and errors were replaced with the mean of the correct responses in that response block plus a 600 millisecond penalty. Positive scores indicated a gender sex-science belief (i.e., *female + sex/male + science*). Scores could range from +2 to −2, with zero indicating neutrality or no difference in association of either attribute (sex or science) with either gender category (female or male). Using standard criteria, participants whose results were indicative of careless participation were excluded from our data. That

is, we removed participants who (1) made more than 30% errors or (2) were faster than 350 ms on more than 10% of the critical trials.

Results showed a large association of female + sex/male + science ($M = 0.38$, $SD = 0.41$, Cohen's $d = 0.93$, $t(212) = 13.476$, $p < 0.01$, 95% C.I. [0.32, 0.44]). That is, participants associated the category *female* more with the attribute *sex* and the category *male* more with the attribute *science*.

Explicit gender sex-science beliefs

Results from items assessing explicit associations were combined into a single score. That is, we averaged the differences in responses between items that assessed the associations of the two gender categories (i.e., *female* and *male*) with the attributes *science* and *sex*:

$$[(\text{“}male + science\text{”} - \text{“}female + science\text{”}) + (\text{“}female + sex\text{”} - \text{“}male + sex\text{”})]/2$$

Positive scores indicated *female + sex/male + science* associations. Explicit scores could range from +3 to −3 with zero indicating no relative association.

In contrast to the data obtained on the measure of implicit cognition, results showed no explicit association between categories and attributes ($M = -0.06$, $SD = 0.74$, Cohen's $d = -0.08$, $t(205) = -1.076$, $p = 0.283$, 95% C.I. [−0.16, 0.05]). That is, participants equally associated the categories female and male with the attributes science and sex.

Implicit and explicit correlation

Implicit and explicit measures of gender sex-science beliefs were uncorrelated ($r = -0.05$, $p = 0.939$). This result is consistent with previous research showing no or low correlations between implicit and explicit measures (Marini, 2017; Marini et al., 2013; Nosek, 2007; Nosek et al., 2002) as the latter is a report of what one aspires to rather than what has been learned through experience. Implicit and explicit correlations and scores by experiment are reported in Table 1.

Experiment 1 achieved the purpose of providing the first test of the implicit and explicit association between gender (male, female) and the attributes of sex vs. science. The results are clear. In the general population, we see a strong association of *female + sex/male + science* on the implicit measures, whereas no such association is observed on the explicit measures.

Experiment 2

Although the standard IAT procedure has many positive features as a measure of implicit cognition, it suffers from a constraint that becomes

theoretically relevant here. The IAT provides a combined measure of associations between two categories and two attributes that cannot be decomposed. That is, in our case, it is not possible to know whether the IAT scores found in Experiment 1 reflect a stronger *female + sex* association or a stronger *male + science* association. All we can say with confidence is that there is a stronger association of *female* with *sex* and *male* with *science*. The decomposition of the two associations (i.e., *female + sex* and *male + science*) is thus crucial to understand whether the gender-sex bias is driven primarily by one of them. In particular, Experiments 2 tests whether the *female + sex/male + science* association found in Experiment 1 may reflect a stronger association of the category *female* with *sex* versus *science* or a stronger association of the category *male* with *science* versus *sex*.

To address this issue and decompose the two components, in Experiment 2 implicit associations were measured by means of a Single Category Implicit Association Test (SC-IAT) (Karpinski & Steinman, 2006), a modified version of the IAT which allows decomposition of scores. The SC-IAT has the same basic structure of the IAT with the difference that only one category (or attribute) is presented with two attributes (or categories). Specifically, in Experiment 2, we measured the association between the category *female* ("Female" condition) or *male* ("Male" condition) alone with the attributes *sex* and *science*.

Methods

Participants

471 participants were recruited at the Project Implicit website (https://implicit.harvard.edu): 226 participants were assigned to the "Female" condition (M_{age}= 34.31, SD_{age}= 15.66, 74.0% women, 78.3% U.S. citizens/residents, 71.4% Whites), and 245 participants were assigned to the "Male" condition (M_{age}= 33.60, SD_{age}= 14.64, 58.3% women, 80.4% U.S. citizens/residents, 73.1% Whites).

Procedure

Participants were randomly assigned to two primary conditions ("Female" or "Male" condition). The "Female" condition tested the association of *female* alone to attributes *sex* and *science*, while the "Male" condition assessed the association of *male* alone to attributes *sex* and *science*. Procedure was the same as in Experiment 1, with the only exception that participants completed a Single Category Implicit Association Test (SC-IAT) instead of an IAT to measure the implicit associations.

Materials

Measure of implicit gender sex-science beliefs

Implicit associations were assessed by using a Single Category Implicit Association Test (SC-IAT). As in the IAT, in the SC-IAT participants classified stimuli by pressing one of two response keys. In one critical block, participants paired *female* ("Female" condition) or *male* ("Male" condition) and *sex* by using a single key to sort them and a different key to sort *science* items. Then they switched to pair *female* ("Female" condition) or *male* ("Male" condition) and *science* by using a single key and a different key to sort sex items. The difference in average categorization latency between the two critical blocks was used as an indicator of the gender sex-science belief. Critical blocks were randomized across participants, and stimuli were presented one at a time on the center of the computer screen. Stimuli for the categories *male* and *female* and the attributes *sex* and *science* were the same as in Experiment 1.

Measure of explicit gender sex-science beliefs

Two items were used to assess explicit associations between the attributes *sex* and *science* and the gender category *male* ("Male" condition) or *female* ("Female" condition). Participants were asked to rate the extent to which they associated the gender category *male* ("Male" condition) or *female* ("Female" condition) to the attributes *science* and *sex* on a 4-point scale ranging from 0 to 3 (e.g., 0 "Not at all sex/science" and 3 "Strongly sex/science").

Results and discussion

Implicit gender sex-science beliefs

SC-IAT scores were computed as IAT scores in Experiment 1. Positive scores indicated a *female* + *sex* association in the "Female" condition and a *male* + *science* association in the "Male" condition. Scores could range from +2 to −2, with zero indicating neutrality.

Results showed the presence of a *female* + *sex* association in the "Female" condition ($M = 0.23$, $SD = 0.30$, Cohen's $d = 0.77$, $t(153) = 9.552$, $p < 0.01$, 95% C.I. [0.18, 0.28]) but no significant association was observed in "Male" condition ($M = -0.04$, $SD = 0.30$, Cohen's $d = -0.13$, $t(152) = -1.595$, $p = 0.113$, 95% C.I. [−0.09, 0.01]). That is, when considering women as a category, participants favored the association to sex relative to science. However, when considering men as a category, data reveal an equal association of men with sex and science.

Explicit gender sex-science beliefs

For each condition ("Female" and "Male" conditions), results of two items assessing explicit associations were combined into a single score. That is, we computed the difference between responses on the two items assessing the associations of the category *female* ("Female" condition) or *male* ("Male" condition) with the attributes *sex* and *science:*

"Female" condition = *"female + sex"* – *"female + science"*

"Male" condition = "*male + science"* – "*male + sex"*

Positive scores in the "Female" condition indicated *female + sex* associations, whereas positive scores in the "Male" condition indicated *male + science* associations. Explicit scores could range from +3 to −3 with zero indicating no relative association.

In both conditions, no significant explicit stereotype was found ("Female" condition: $M = -0.11$, $SD = 1.66$, Cohen's $d = -0.07$, $t(150) = -0.834$, $p = 0.406$, 95% C.I. [−0.38, 0.15]; "Male" condition: $M = -0.01$, $SD = 1.54$, Cohen's $d = -0.01$, $t(152) = -0.052$, $p = 0.958$, 95% C.I. [−0.25, 0.24]).

Implicit and explicit correlation

Implicit and explicit measures were uncorrelated ("Female" condition: $r = -0.07$, $p = 0.429$; "Male" condition: $r = 0.09$, $p = 0.254$).

These results replicate to strengthen confidence in the implicit association of the category female to sexual attributes compared with scientific ones; they also show that the category male is, by contrast, equally associated with sexual and scientific attributes. The value of Experiment 2 lies in the discovery that it is the *female + sex* association that is most clear, as the category male is malleable enough to be associated with both attributes.

Experiment 3

The single category task used in Experiment 2 served the function of decomposing associations to reveal how each category, female and male, independently relates to the attributes of sex and science. The inverse decomposition is not only possible but it would provide unique information. In Experiment 3, we begin with the attribute *sex* ("Sex" condition) and test the strength of association between this attribute to female relative to male. Then, we move to the attribute *science* ("Science" condition) and similarly measure its association to female relative to male. We do this because the *female + sex/male + science* association found in Experiment 1 may reflect a stronger association of the attribute *science* with *male* versus *female* or a stronger association of the attribute *sex* with *female* versus

male. Jointly, Experiments 2 and 3 would provide clear evidence of the unique association of *female* and *male* to *sex* and science.

Methods

Participants

454 participants were recruited at the Project Implicit website (https://implicit.harvard.edu). 240 participants were assigned to the "Sex" condition (M_{age}= 33.39, SD_{age}=15.94, 64.1% women, 65.8% U.S. citizens/residents, 67.2% Whites), and 214 participants were assigned to the "Science" condition (M_{age}= 31.93, SD_{age}=14.96, 61.7% women, 79% U.S. citizens/residents, 67.2% Whites).

Procedure

Participants were randomly assigned to a "Sex" or "Science" condition. The "Sex" condition tested the association of the attribute *sex* alone to categories *female* and *male*; while the "Science" condition measured the association of the attribute *science* alone to categories *female* and *male*. Procedure was the same as in Experiment 2.

Materials

Measure of implicit gender sex-science beliefs

As in Experiment 2, implicit gender sex-science belief was assessed by using a Single Category Implicit Association Test (SC-IAT). In the "Sex" condition, participants classified stimuli representing the attribute *sex* and the categories *female* and *male*. In the "Science" condition, participants categorized stimuli belonging to the attribute *science* and the categories *female* and *male*. Task procedure, stimuli, and categories were the same as in Experiments 2.

Measure of explicit gender sex-science beliefs

Two items were used to assess explicit associations between the categories *male* and *female* and the attribute *sex* ("Sex" condition) or *science* ("Science" condition). Participants were asked to rate the extent to which they associated the attribute *sex* or *science* to the categories *female* and *male* on a 4-point scale ranging from 0 to 3 (e.g., 0 "Not at all male/female" and 3 "Strongly male/female").

Results and discussion

Implicit gender sex-science beliefs

SC-IAT scores were computed as IAT scores in Experiment 1. Positive scores indicated a *female + sex* association in the "Sex" condition and a *male + science* association in the "Science" condition. Scores could range from +2 to −2, with zero indicating neutrality.

Results showed that in the "Sex" condition a clear association of that attribute to female compared to male exists ($M = 0.12$, $SD = 0.33$, Cohen's $d = 0.36$, $t(153) = 4.377$, $p < 0.01$, 95% C.I. [0.06, 0.17]) but no significant association was observed in "Science" condition ("Science": $M = 0.04$, $SD = 0.33$, Cohen's $d = 0.12$, $t(152) = 1.508$, $p = 0.134$, 95% C.I. [−0.01, 0.93]).

Explicit gender sex-science beliefs

For each condition ("Sex" and "Science" conditions), results of two items assessing explicit associations were combined into a single score. That is, we computed the difference between the responses on the two items assessing the associations of the attribute *sex* ("Sex" condition) or *science* ("Male" condition) with the categories male and female:

"Sex" condition = "female + sex" – "male + sex"

"Science" condition = "male + science" – "female + science"

Positive scores in the "Sex" condition indicated female + sex associations, whereas positive scores in the "Science" condition indicated male + science associations. Explicit scores could range from +3 to −3 with zero indicating no relative association.

No significant explicit stereotype was found in the "Sex" condition ($M = 0.12$, $SD = 1.12$, Cohen's $d = 0.11$, $t(155) = 1.357$, $p = 0.177$, 95% C.I. [−0.06, 0.30]), while in the "Science" condition we found that the attribute science was more associated with the category female than male ($M = -0.28$, $SD = 0.84$, Cohen's $d = -0.33$, $t(153) = -4.144$, $p < 0.01$, 95% C.I. [−0.41, −0.15]), suggesting participants' desire to explicitly challenge existing stereotypes via counterstereotypical responses. Such behavior provides insight into the difference between explicit and implicit cognition. The latter reveals the thumbprint of culture, irrespective of one's conscious values. The former can be normatively shaped to reflect the state of the world one hopes for. In fact, even if the world as it should be, is one in which male and female are equally associated with science, the response here, claiming the opposite of the state of affairs, is a good example of one of the functions of explicit attitudes and beliefs, i.e., to express one's values which is impossible to communicate on measures of implicit cognition.

Implicit and explicit correlation

Implicit and explicit measures were uncorrelated ("Sex" condition: $r = 0.05$, $p = 0.548$; "Science" condition: $r = -0.05$, $p = 0.581$).

Results of Experiment 3 show that the attribute *sex* is implicitly more associated with the gender category *female* than *male*, while no association between the attribute *science* and the categories *female* or *male* is found. On the contrary, explicit measures show that the attribute *science* is more associated with the category *female* than *male* (demonstrating an explicit challenge to gender stereotypes), while no association between the attribute *sex* and the categories *female* or *male* is observed.

Taken together, Experiments 2 and 3 help to decompose the overall IAT effect. They reveal that the category female has an implicit association to sex relative to science and that the category sex is also more strongly associated with female than male. Conversely, the categories male and science are neutral; male is equally associated to both sex and science and the concept of science is, in and of itself, gender neutral.

Experiment 4

Experiment 1 used generic gender categories, *male* and *female*. In Experiment 4, we tested whether the implicit gender sex-science belief emerged even when gender categories were explicitly represented as scientists. We thus replaced in the implicit and explicit measures the categories *female* and *male* with *female scientist* and *male scientist* and used pictures of female and male scientists integrated with highly visible and explicit symbols of science (e.g., goggles, lab coats, masks, and microscopes).

Methods

Participants

795 participants ($M_{age} = 31.53$, $SD_{age} = 13.45$, 63.7% women, 72.3% U.S. citizens/residents, 73.8% Whites) were recruited at Project Implicit website (https://implicit.harvard.edu).

Procedure

Procedure was the same as in Experiment 1.

Materials

Measures of implicit gender sex-science beliefs

The IAT measured the associations between the categories *female scientists* and *male scientists* and the attributes *sex* and *science*. Pictures portraying

male/female scientists were used as stimuli for the gender categories *female scientists* and *male scientists*, whereas different words referring to science and to act of sex were used as stimuli for the attributes *science* and *sex* (Table S1, Supporting Information). The IAT task procedure was the same as in Experiment 1.

Measures of explicit gender sex-science beliefs

Explicit beliefs were assessed by means of four self-reported items assessing explicit associations between the gender categories *female scientists* and *male scientists* and the attributes *science* and *sex*. In each item, participants were asked to rate the extent to which they associated each set of pictures portraying *male scientists* or *female scientists* to the attributes *science* and *sex* on a 4-point scale ranging from 0 to 3 (e.g., 0 "Not at all sex" and "Strongly sex"; Table S2, Supporting Information).

Results and discussion

IAT and explicit data were prepared and analyzed exactly as in Experiment 1. Positive IAT or explicit scores indicated an implicit or an explicit gender sex-science belief (i.e., *female + sex/male + science*), respectively.

Implicit gender sex-science beliefs

Data from Experiment 4 again showed the presence of a strong implicit *female + sex/male + science* association ($M = 0.30$, $SD = 0.39$, Cohen's $d = 0.77$, $t(772) = 21.24$, $p < 0.01$, 95% C.I. [0.27, 0.33]) as observed in Experiment 1.

Explicit gender sex-science beliefs

Data showed the presence of a *female + sex/male + science* association ($M = 0.13$, $SD = 0.42$, Cohen's $d = 0.31$, $t(777) = 8.29$, $p < 0.01$, 95% C.I. [0.10, 0.16]).

Implicit and explicit correlation

Implicit and explicit scores were weakly correlated ($r = 0.10$, $p < 0.01$).

Results from Experiment 4 show that the implicit gender sex-science belief found in Experiment 1 strongly emerges even when gender categories are explicitly represented as scientists by using pictures of female and male scientists working in a lab. This belief is observed also on explicit measures, although the effect size is half the magnitude of the implicit measures. These latter results suggest explicit awareness of gender-science stereotypes.

Experiment 5

In Experiment 5, we evaluated whether the implicit gender sex-science belief emerged even when stimuli for the categories *female scientist* and *male scientist* were represented by words instead of pictures as in Experiment 4.

We do this to exclude that the *female + sex/male + science* association found in Experiment 4 may be uniquely a function of physical representations of the two groups. Would the effect also emerge in verbal representations of the two groups? In Experiment 5, we used female and male first names followed or preceded by a scientific profession as stimuli (e.g., *Brian Physicist* or Lisa *Chemist*) in addition to the primary reminder visible in the category labels of *male scientist and female scientist*.

Methods

Participants

In Experiment 5, 293 participants (M_{age}= 34.14, SD_{age}= 14.93, 65.7% women, 70% U.S. citizens/residents, 66.9% Whites) were recruited at Project Implicit website (https://implicit.harvard.edu).

Procedure

The design and procedure of Experiment 5 were identical to those of Experiment 4 with the primary difference being that Experiment 4 used pictorial stimuli of male and female scientists and Experiment 5 used first names and scientific discipline to denote individual gender identity and scientific affiliation of the individual (male and female) scientist.

Materials

Measure of implicit gender sex-science beliefs

As noted, Experiment 4 used words instead of pictures as stimuli for the gender categories *female scientist* and *male scientist*. Specifically, stimuli for the categories *female scientist* and *male scientist* were composed of two words: female/male first name followed or preceded by a scientist profession (e.g., *Brian, Physicist* or Lisa*, Chemist* and *Engineer, Tom* or *Biologist, Audrey*; Table S1, Supporting Information). The order of the two words was counterbalanced in the experiment. Female and male names were analogues in terms of attractiveness and competence (Kasof, 1993).

Measure of explicit gender sex-science beliefs

Explicit items were the same as Experiment 4, with the only exception that no set of pictures was presented. Participants were asked to rate the extent to which they associated each gender category *male scientists* or *female scientists* to the attributes *science* and *sex* on a 4-point scale ranging from 0 to 3 (e.g., 0 "Not at all sex" and "Strongly sex"; Table S2 Supporting Information).

Results and discussion

IAT and explicit data were prepared and analyzed exactly as in Experiment 1. Positive IAT or explicit scores indicated an implicit or an explicit gender sex-science belief (i.e., *female + sex/male + science*), respectively.

Implicit gender sex-science beliefs

IAT results showed the presence of *female + sex/male + science* associations ($M = 0.20$, $SD = 0.43$, Cohen's $d = 0.47$, $t(156) = 5.939$, $p < 0.01$, 95% C.I. [0.14, 0.27]).

Explicit gender sex-science beliefs

The *female + sex/male + science* association was observed also on explicit beliefs, ($M = 0.12$, $SD = 0.58$, Cohen's $d = 0.21$, $t(153) = 2.556$, $p < 0.05$, 95% C.I. [0.03, 0.21]), although the effect size was halved on self-reports relative to the IAT.

Implicit and explicit correlation

Implicit and explicit scores showed a positive correlation ($r = 0.23$, $p < 0.01$).

Results from Experiment 5 show that implicit gender sex-science belief emerges even when stimuli for the categories *female scientist* and *male scientist* are represented by words instead of pictures, as in Experiment 4. This belief is also weakly observed at the explicit level.

Together, Experiments 4 and 5 show that a weak explicit, self-reported association is matched by a strong implicit gender sex-science association that persisted even when *female* and *male* targets were explicitly represented as scientists both visually and verbally.

Experiment 6

All experiments conducted thus far invited volunteers from the general population to be participants. In Experiment 6, we evaluated the presence

of the sex-science belief in faculty in STEM fields. Although the effect was observed in the general population, there is good reason to expect that STEM faculty are protected from such bias given their many experiences with training future generations of male and female scientists in the classroom and lab. In other words, those who are in the business of STEM education may not show the same bias as did members of the general population. In Experiment 6, we undertook the effort of recruiting faculty from the highest ranked U.S. universities in STEM to measure their gender sex-science associations.

Methods

Participants

Faculty members were recruited by sending an invitation e-mail to 4,555 scientists (i.e., professors, lecturers, instructors, research associates, and postdoctoral fellows) from the top 14 universities in the US (i.e., the top 7 national-ranked universities and the top 7 STEM universities). This large number of potential participants was identified because of the realistic expectation that very few would chose to participate in a study that arrived as an invitation in their email inbox. We selected scientists only from STEM fields, i.e., astronomy/astrophysics, chemistry, biology, computer science, engineering, mathematics, and physics. Each scientist was contacted only once, as per our commitment in the IRB application so as not impinge on the time of those who did not wish to participate. One hundred and fifty six faculty members (28.4% women) completed the study (3.42% of all invited faculty).

Procedure and materials

Procedure and materials were identical to those used in Experiment 1 so as to be able to compare the results from STEM faculty to those from members of the general population.

Results and discussion

IAT and explicit data were prepared and analyzed exactly as in Experiment 1. Positive IAT or explicit scores indicated an implicit or an explicit gender sex-science belief (i.e., *female + sex/male + science*), respectively.

Implicit gender sex-science beliefs

On the IAT, results showed that faculty from the nation's premier science departments also hold a strong *female + sex/male + science* association ($M = 0.39$, $SD = 0.41$, Cohen's $d = 0.95$, $t(153) = 11.884$, $p < 0.01$, 95% C.I.

[0.33, 0.45]) on par with the effect observed in the general population (Experiment 1: $M = 0.38$, $SD = 0.41$, Cohen's $d = 0.93$, $t(212) = 13.476$, $p < 0.01$, 95% C.I. [0.32, 0.44], $F(1,366) = 0.050$, $p = 0.822$, $\eta p^2 = 0.00$).

Explicit gender sex-science beliefs

STEM faculty also explicitly reported weak associations of *female* with *sex* and male with *science* ($M = 0.22$, $SD = 0.86$, Cohen's $d = 0.26$, $t(150) = 3.092$, $p < 0.01$, 95% C.I. [0.08, 0.35]).

Implicit and explicit correlation

No correlation was observed between explicit and implicit scores ($r = 0.02$, $p = 0.790$).

The results of Experiment 6 are important in showing that the gender bias revealed by these studies of greater *female + sex/male + science* association are also present in STEM faculty who work at the highest-ranked U.S. universities to the same extent as they exist in the population at large. In addition, STEM faculty showed a weak *female + sex/male + science* association on the explicit measures, even though no such result was observed in Study 1 with the general population.

A test of the explanatory role of sexual attraction in the gender sex-science association

The implicit gender sex-science belief observed in our experiments may reflect sexual attraction to females, on the part of men and women whose sexual orientation favors female rather than male. That is, it can be argued that the result is not one of greater objectification of women or a general inability to associate *female* with *science* (relative to *sex*), but rather that the result of the studies simply reflects the sexual attraction of heterosexual men and gay women for women. In other words, if only heterosexual men and gay women show the gender sex-science association, the conclusion from these studies would need to be far more circumscribed than if the effect emerges more generally in all men and women, irrespective of sexual orientation. To provide the greatest statistical power to detect this effect, we aggregated our samples ($N = 1{,}589$, 62.9% women) across all experiments conducive to such a comparison (Experiments 1, 4, 5, and 6). First, and unsurprisingly, we found that reported gender and sexual attraction scores were highly correlated ($r = 0.92$, $p < 0.01$). That is, women overall report sexual attraction to men, and men overall report sexual attraction to women. We thus submitted the IAT scores to two separate regression models, one for each of the two factors (i.e., gender and sexual attraction).

Results of this meta-analysis (Table 2) showed no significant effect of gender, $\beta = 0.048$, $t(1278) = 1.722$, $p = 0.085$, 95% C.I. [−0.01, 0.09]. In other words, female participants ($M = 0.30$, $SD = 0.40$, Cohen's $d = 0.75$, $t(788) = 20.704$, $p < 0.01$, 95% C.I. [0.27, 0.33]) showed implicit *female + sex/male + science* associations that were remarkably similar to male participants ($M = 0.34$, $SD = 0.40$, Cohen's $d = 0.85$, $t(489) = 18.578$, $p < 0.01$, 95% C.I. [0.30, 0.37]). Such an analysis demonstrates that the observed effect cannot easily be attributed to gender.

In the regression model involving the variable of sexual attraction, a significant effect on IAT scores was observed, $\beta = 0.151$, $t(332) = 2.781$, $p < 0.01$, 95% C.I. [0.04, 0.21]. That is, although all participants irrespective of sexual orientation associated *female* with *sex* and *male* with *science*, those who reported sexual attraction toward women showed stronger implicit *female + sex/male + science* associations ($M = 0.46$, $SD = 0.39$, Cohen's $d = 1.18$, $t(149) = 14.412$, $p < 0.01$, 95% C.I. [0.40, 0.52]) than participants who reported being attracted to men ($M = 0.33$, $SD = 0.42$, Cohen's $d = 0.79$, $t(182) = 10.722$, $p < 0.01$, 95% C.I. [0.27, 0.40]). However, both effects are at or above the 0.80 cutoff that marks an effect as large (Cohen, 1977).

These results show that the implicit gender sex-science belief observed in these experiments cannot be interpreted simply as an outcome of sexual orientation. In fact, women (the majority of whom report sexual attraction for men) showed the gender sex-science effect as strongly as men. Moreover, those who reported a sexual preference for women showed the effect (Cohen's $d = 1.18$) on par with those who reported sexual preference for men (Cohen's $d = 0.79$).

General discussion

In summary, across all experiments, data showed evidence of an implicit gender sex-science belief such that *female* more than *male* was associated with *sex* relative to *science* (Table 1). This effect (1) was observed in multiple experiments with large samples of the general population (Experiments 1, 2, 3, 4, and 5); (2) was observed equally among faculty from the nation's preeminent institutions of higher learning in STEM (Experiment 6); (3) was observed among women and men participants (meta-analysis); (4) was observed in participants with different sexual attraction (meta-analysis); (5) persisted even when *female* and *male* were represented clearly as scientists (Experiments 4 and 5); (6) persisted even when the methodological constraint of the IAT was removed (Experiments 2 and 3); (7) showed dissociation from explicit gender sex-science stereotypes which were either small or nonexistent (Experiments 1, 2, 3, 4, 5 and

6). The strength and generality of the *female + sex/male + science*, in other words, is robust and pervasive.

We suggest that the implicit gender sex-science belief observed robustly here is a product of historical and present-day representations of the categories *male* and *female* as we learn and experience them as members of society. Specifically, that attributes of *mind*, such as *science* (Miller, Eagly, & Linn, 2015; Nosek et al., 2009; Régner, Thinus-Blanc, Netter, Schmader, & Huguet, 2019), are relatively masculine attributes, while attributes of the *body*, such as *sex* (Gervais et al., 2012; Wu, 2017), are relatively feminine attributes. Consequently, both long-held traditions and present-day expressions in society may play a role in the gender sex-science beliefs in the minds of individuals. They have created and maintained the idea that men are naturally predisposed to engage in activities of the *mind*, of which the scientific endeavor is a prototypic example. Similarly, women are viewed as creatures whose *body* is the primary instrument of interacting with the world, originating in the role they play in reproduction and nurturance. Future research, investigating the specific associations between the categories *female* and *male* and the attributes *mind* and *body*, would be valuable evidence in support of this hypothesis. Such studies will also be able to derive more precise indications of the types of experiences that produce variations in such a bias. Given that those who report sexual attraction to men show a strong gender sex-science belief (Cohen's $d = 0.79$), we can conclude that the observed association cannot be explained as originating in sexual attraction for women.

The gender sex-science association observed across all six experiments must be taken as evidence that a majority holds this association and in the absence of other obvious origin hypotheses, the most parsimonious one at this time is the biological role played by women and men that came to be codified, with broad strokes, in representations of them in areas that have little to do with differences in reproduction and nurturance. Sexual objectification is one such idea, and the data from these six experiments are consistent with the hypothesis that the association of female with "body" and "sex" that are present in spoken language and all forms of textual representations as well as in individual interactions and in media representations are the source of the associations we observed on the measure of implicit cognition. It points in no small way to the idea that these reflections are a function of the thumbprint of culture on human minds, given that the effect emerges even in those who report no sexual preference for women.

Evidence from depictions in the media show that two-thirds of all the scientists portrayed in film and television are male (Lyda Hill Foundation & the Geena Davis Institute on Gender in Media, 2018), while women are portrayed in a sexually objectified manner in 71% of music videos (Frisby

& Aubrey, 2012), among 45.5% of young adult female characters on primetime TV (Smith, Choueiti, Prescott, Piper, & The Annenberg School for Communication & Journalism, 2012), and in 22% of TV commercials featuring women (Messineo, 2008). Similarly, survey studies showed that women in science report stories of sexual advances and comments from male partners in the lab (Clancy, Nelson, Rutherford, & Hinde, 2014; Richey, 2015). Furthermore, research has shown that women in STEM fields tend to minimize their feminine appearance because they are concerned about being viewed as unsuitable for a STEM career or because they wish to avoid drawing attention to their gender altogether (Pronin, Steele, & Ross, 2004). This finding is in line with studies indicating that feminine women are perceived as less suitable for science (Banchefsky, Westfall, Park, & Judd, 2016). In fact, Nosek, Banaji, and Greenwald (2002) showed that the stronger women's association between self and "female", the weaker their liking for mathematics and science. In future research, examining women's own identity with sex versus science, and testing this association among women scientists may reveal the degree to which these culturally dominant beliefs have entered into women's own self-concept—even in those who have chosen a career in science. Other studies may be directed at investigating these associations in the minds of women as a predictor of who stays and who leaves a STEM career.

While our results consistently showed the presence of a strong implicit gender sex-science belief across all experiments, variations in the strength of this belief were observed. That is, large effects were slightly muted when implicit gender sex-science beliefs were assessed using the SC-IAT compared to the standard IAT. This is not unexpected, as SC-IATs tend to produce smaller effects than the standard IAT (Bar-Anan & Nosek, 2014). Similarly, when verbal material was used to represent gender (e.g., names) the effect was robustly present but still slightly weaker than one observed with visual representations (e.g., photos). Again, photos rather than verbal labels may more directly access gender and as such produce a larger effect (Foroni & Bel-Bahar, 2009). Both issues are not unique to this study, but more generally observed in the IAT literature. Given the fast improvements in research on implicit social cognition, future studies are sure to provide more clarity. The important point here is that the effects, even when weaker in one condition than another, are themselves robust.

In addition, we found that for some experiments the gender sex-science belief was observed also on explicit measures, suggesting a potential awareness of these associations also at a conscious level. However, it is important to note that across all the experiments, the effects on the IAT ($M = 0.31$, $SD = 0.41$, Cohen's $d = 0.76$, $t(1296) = 27.74$, $p < 0.001$, 95% C.I. [0.29,

0.33]) are vastly stronger than on explicit measures ($M = 0.11$, $SD = 0.57$, Cohen's $d = 0.19$, $t(1288) = 6.68$, $p < 0.001$, 95% C.I. [0.08, 0.14]).

Average IAT scores have been shown to differ by geographic region (Marini et al., 2013; Nosek et al., 2009) and such differences in turn have been shown to predict behavior. For example, several studies have shown that the magnitude of the IAT race score by region predicts outcomes such as lethal use of force by police (Hehman, Flake, & Calanchini, 2018); ingroup death rate for Blacks and Whites (Leitner, Hehman, Ayduk, & Mendoza-Denton, 2016); the black-white gap in infant health outcomes (Orchard & Price, 2017); and racial disparities in school-based disciplinary actions (Riddle & Sinclair, 2019) among other effects. Two studies have specifically shown correlation between IAT gender stereotype scores by country and male-female differences in science and math achievement (Nosek et al., 2009) and women's representation in science (Miller et al., 2015). Future research may be able to measure the sex-science association to gender to not only predict gender representation and performance in STEM fields, but to use it to track women's own beliefs about achievement and identity with science, their progress through the ranks, and their ability to contribute fully to the production of science. The present results hold up a mirror in which many (including the authors of this manuscript) see a reflection that they may not otherwise recognize and that may nevertheless be difficult to believe and accept. In fact, in conducting Experiment 6 with faculty from STEM departments, we encountered outright hostility from some participants, which we take to signal their displeasure at even the idea of examining such a stereotype.[1]

The manner in which societies represent and treat the social groups inside them have meaning for how individuals are perceived, evaluated, and judged as well as the actions that are taken toward them. For reasons that have roots deep in our evolutionary history and the general roles that came to be, male and female have repeatedly been set in opposition to each other: the one as rational and intelligent, the other as emotional and intuitive. These beliefs linger and are even resistant to change and they have shaped who gets to participate in the activities of science today. Even though beliefs such as "girls can't do science" are outdated and our own explicit data show this, there is a lingering presence of the belief that science belongs to men more than women. In support, we point to research by Meyer, Cimpian, and Leslie et al. (2015) who reported that academic fields that adhere to the belief that "raw intellectual talent" is required to succeed (mathematics, physics, philosophy) also had fewer women in their ranks; additionally, academic fields that laypeople viewed as requiring "brilliance" were also fields with lower female representations.

In this paper, we report the first evidence of a robust and pervasive implicit gender sex-science belief. The data also show that the female + sex association drives this effect, as science appears to be equally associated with male and female in our tests (see, Experiment 3). To allow the best talent in science to emerge and be utilized to solve society's many challenges, it is important to be aware that even today, whatever our conscious beliefs may be, our minds undeniably carry the implicit associations of female + sex/male + science. This is true of the minds of women and men, whether they are laypeople or STEM faculty, and across variations in category representation and IAT procedures. No evidence exists at present that we can point to that would contradict this result.

Can implicit stereotypes change over time? Can they fade away such that attributes like "science" or "career" become gender neutral? Charlesworth and Banaji (2020) have shown that over a ten-year period, the stereotype of female + arts and male + science has weakened by 13% and this change is much greater in women than men. More generally, the authors report a change in the stereotype associating female + home and male + career by 17% over the same period. The observation of significant change in gender beliefs, visible even over a mere decade, bodes well for the possibility that neutrality in gender sex-science stereotypes is within reach. To the extent that implicit stereotypes are reflections of the collective, i.e., the mind of a society, a result of stereotype gender neutrality (for *career* and *science*) will likely obtain when individual minds lack any reason to continue to hold the belief of *male + science* and *female + sex*. That is, the data from measures of implicit stereotypes will reveal neutrality but only when the world it reflects has achieved gender neutrality.

Note

1. Two faculty members who were included in the sample of STEM faculty recruited wrote these messages to us.
   Email #1:
   Dear Prof. Banaji,
   I have many outstanding female, male, and transgendered etc. students who I mentor in research. I did not go through your post-doc's whole survey but half of it was more than enough. I have been a visitor to Harvard many times and enjoyed my interactions with faculty in physics there. I don't think you are doing women in science any favors with this exercise, nor is it reflecting well on Harvard. I really doubt Harvard faculty as a whole will be happy with what you are doing.
   I would cc your department head/chair, but it seems this is actually yourself. I have therefore cc'ed your dean ….
   Sincerely,
   Email #2:
   I will be happy to participate if this is a genuine, open-minded survey about the scientific enterprise itself.

On the other hand, if it is a survey about "implicit bias," with a hidden agenda, I am somewhat reluctant to become involved. Please be somewhat more forthcoming about the focus of the survey.

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