Despite efforts to recruit and retain more women, a stark gender disparity persists within academic science. Abundant research has demonstrated gender bias in many demographic groups, but has yet to experimentally investigate whether science faculty exhibit a bias against female students that could contribute to the gender disparity in academic science. In a randomized double-blind study \((n = 127)\), science faculty from research-intensive universities rated the application materials of a student—who was randomly assigned either a male or female name—for a laboratory manager position. Faculty participants rated the male applicant as significantly more competent and hirable than the (identical) female applicant. These participants also selected a higher starting salary and offered more career mentoring to the male applicant. The gender of the faculty participants did not affect reactions, such that female and male faculty were equally likely to exhibit bias against the female student. Mediation analyses indicated that the female student was less likely to be hired because she was viewed as less competent. We also assessed faculty participants’ preexisting subtle bias against women using a standard instrument and found that preexisting subtle bias against women played a moderating role, such that subtle bias against women was associated with less support for the female student, but was unrelated to reactions to the male student. These results suggest that interventions addressing faculty gender bias might advance the goal of increasing the participation of women in science.

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Science faculty’s subtle gender biases favor male students

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Edited* by Shirley Tilghman, Princeton University, Princeton, NJ, and approved August 21, 2012 (received for review July 2, 2012)

Despite efforts to recruit and retain more women, a stark gender disparity persists within academic science. Abundant research has demonstrated gender bias in many demographic groups, but has yet to experimentally investigate whether science faculty exhibit a bias against female students that could contribute to the gender disparity in academic science. In a randomized double-blind study \((n = 127)\), science faculty from research-intensive universities rated the application materials of a student—who was randomly assigned either a male or female name—for a laboratory manager position. Faculty participants rated the male applicant as significantly more competent and hirable than the (identical) female applicant. These participants also selected a higher starting salary and offered more career mentoring to the male applicant. The gender of the faculty participants did not affect reactions, such that female and male faculty were equally likely to exhibit bias against the female student. Mediation analyses indicated that the female student was less likely to be hired because she was viewed as less competent. We also assessed faculty participants’ preexisting subtle bias against women using a standard instrument and found that preexisting subtle bias against women played a moderating role, such that subtle bias against women was associated with less support for the female student, but was unrelated to reactions to the male student. These results suggest that interventions addressing faculty gender bias might advance the goal of increasing the participation of women in science.
bias because they have been rigorously trained to be objective. On the other hand, research demonstrates that people who value their objectivity and fairness are paradoxically particularly likely to fall prey to biases, in part because they are not on guard against subtle bias (24, 25). Thus, by investigating whether science faculty exhibit a bias that could contribute to the gender disparity within the fields of science, technology, engineering, and mathematics (in which objectivity is emphasized), the current study addressed critical theoretical and practical gaps in that it provided an experimental test of faculty discrimination against female students within academic science.

A number of lines of research suggest that such discrimination is likely. Science is robustly male gender-typed (26, 27), resources are inequitably distributed among men and women in many academic science settings (28), some undergraduate women perceive unequal treatment of the genders within science fields (29), and nonexperimental evidence suggests that gender bias is present in other fields (19). Some experimental evidence suggests that even though evaluators report liking women more than men (15), they judge women as less competent than men even when they have identical backgrounds (20). However, these studies used undergraduate students as participants (rather than experienced faculty members), and focused on performance domains outside of academic science, such as completing perceptual tasks (21), writing nonscience articles (22), and being evaluated for a corporate managerial position (23).

Thus, whether aspiring women scientists encounter discrimination from faculty members remains unknown. The formative predoctoral years are a critical window, because students’ experiences at this juncture shape both their beliefs about their own abilities and subsequent persistence in science (30, 31). Therefore, we selected this career stage as the focus of the present study because it represents an opportunity to address issues that manifest immediately and also resurface much later, potentially contributing to the persistent faculty gender disparity (32, 33).

Current Study
In addition to determining whether faculty expressed a bias against female students, we also sought to identify the processes contributing to this bias. To do so, we investigated whether faculty members’ perceptions of student competence would help to explain why they would be less likely to hire a female (relative to an identical male) student for a laboratory manager position. Additionally, we examined the role of faculty members’ preexisting subtle bias against women. We reasoned that pervasive cultural messages regarding women’s lack of competence in science could lead faculty members to hold gender-biased attitudes that might subtly affect their support for female (but not male) science students. These generalized, subtly biased attitudes toward women could impel faculty to judge equivalent students differently as a function of their gender.

The present study sought to test for differences in faculty perceptions and treatment of equally qualified men and women pursuing careers in science and, if such a bias were discovered, reveal its mechanisms and consequences within academic science. We focused on hiring for a laboratory manager position as the primary dependent variable of interest because it functions as a professional launching pad for subsequent opportunities. As secondary measures, which are related to hiring, we assessed: (i) perceived student competence; (ii) salary offers, which reflect the extent to which a student is valued for these competitive positions; and (iii) the extent to which the student was viewed as deserving of faculty mentoring.

Our hypotheses were that: Science faculty’s perceptions and treatment of students would reveal a gender bias favoring male students in perceptions of competence and hireability, salary conferral, and willingness to mentor (hypothesis A); Faculty gender would not influence this gender bias (hypothesis B); Hiring discrimination against the female student would be mediated (i.e., explained) by faculty perceptions that a female student is less competent than an identical male student (hypothesis C); and Participants’ preexisting subtle bias against women would moderate (i.e., impact) results, such that subtle bias against women would be negatively related to evaluations of the female student, but unrelated to evaluations of the male student (hypothesis D).

Results
A broad, nationwide sample of biology, chemistry, and physics professors (n = 127) evaluated the application materials of an undergraduate science student who had ostensibly applied for a science laboratory manager position. All participants received the same materials, which were randomly assigned either the name of a male (n = 63) or a female (n = 64) student; student gender was thus the only variable that differed between conditions. Using previously validated scales, participants rated the student’s competence and hireability, as well as the amount of salary and amount of mentoring they would offer the student. Faculty participants believed that their feedback would be shared with the student they had rated (see Materials and Methods for details).

Student Gender Differences. The competence, hireability, salary conferral, and mentoring scales were each submitted to a two (student gender; male, female) × two (faculty gender; male, female) between-subjects ANOVA. In each case, the effect of student gender was significant (all P < 0.01), whereas the effect of faculty participant gender and their interaction was not (all P > 0.19). Tests of simple effects (all d > 0.60) indicated that faculty participants viewed the female student as less competent (t(125) = 3.89, P < 0.001) and less hireable (t(125) = 4.22, P < 0.001) than the identical male student (Fig. 1 and Table 1). Faculty participants also offered less career mentoring to the female student than to the male student (t(125) = 3.77, P < 0.001). The mean starting salary offered the female student, $26,507.94, was significantly lower than that of $30,238.10 to the male student (t(124) = 3.42, P < 0.01) (Fig. 2). These results support hypothesis A.

In support of hypothesis B, faculty gender did not affect bias (Table 1). Tests of simple effects (all d < 0.33) indicated that female faculty participants did not rate the female student as more competent (t(62) = 0.06, P = 0.95) or hireable (t(62) = 0.41, P = 0.69) than did male faculty. Female faculty also did not offer more mentoring (t(62) = 0.29, P = 0.77) or a higher salary (t(61) = 1.14, P = 0.26) to the female student than did their male counterparts.

Fig. 1. Competence, hireability, and mentoring by student gender condition (collapsed across faculty gender). All student gender differences are significant (P < 0.001). Scales range from 1 to 7, with higher numbers reflecting a greater extent of each variable. Error bars represent SEs. nfemale student condition = 63, nfemale student condition = 64.
Evidence emerged for hypothesis C, the predicted mediation (i.e., causal path; see SI Materials and Methods: Additional Analyses for more information on mediation and the results of additional mediation analyses). The initially significant impact of student gender on hireability (β = −0.35, P < 0.001) was reduced in magnitude and dropped to nonsignificance (β = −0.10, P = 0.13) after accounting for the impact of student composite competence (which was a strong predictor, β = 0.69, P < 0.001), Sobel’s Z = 3.94, P < 0.001 (Fig. 3). This pattern of results provides evidence for full mediation, indicating that the female student was less likely to be hired than the identical male because she was viewed as less competent overall.

We also conducted moderation analysis (i.e., testing for factors that could amplify or attenuate the demonstrated effect) to determine the impact of faculty participants’ preexisting subtle bias against women on faculty participants’ perceptions and treatment of male and female science students (see SI Materials and Methods: Additional Analyses for more information on and the results of additional moderation analyses). For this purpose, we administered the Modern Sexism Scale (38), a well-validated instrument frequently used for this purpose (SI Materials and Methods). Consistent with our intentions, this scale measures unintentional negativity toward women, as contrasted with a more blatant form of conscious hostility toward women.

Results of multiple regression analyses indicated that participants’ preexisting subtle bias against women significantly interacted with student gender to predict perceptions of student composite competence (β = −0.39, P < 0.01), hireability (β = −0.31, P < 0.05), and mentoring (β = −0.55, P < 0.001). To interpret these significant interactions, we examined the simple effects separately by student gender. Results revealed that the more preexisting subtle bias participants exhibited against women, the less composite competence (β = −0.36, P < 0.01) and hireability (β = −0.39, P < 0.01) they perceived in the female student, and the less mentoring (β = −0.53, P < 0.001) they were willing to offer her. In contrast, faculty participants’ levels of preexisting subtle bias against women were unrelated to the perceptions of the male student’s composite competence (β = 0.16, P = 0.22) and hireability (β = 0.07, P = 0.59), and the amount of mentoring (β = 0.22, P = 0.09) they were willing to offer him. [Although this effect is marginally significant, its direction suggests that faculty participants’ preexisting subtle bias against women may actually have made them more inclined to mentor the male student relative to the female student (although this effect should be interpreted with caution because of its marginal significance).] Thus, it appears that faculty participants’ preexisting subtle gender bias undermined support for the female student but was unrelated to perceptions and treatment of the male student. These findings support hypothesis D.

Table 1. Means for student competence, hireability, mentoring and salary conferral by student gender condition and faculty gender

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male target student</th>
<th>Female target student</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male faculty</td>
<td>Female faculty</td>
</tr>
<tr>
<td>Competence</td>
<td>4.010 a</td>
<td>4.130 a</td>
</tr>
<tr>
<td>Hireability</td>
<td>3.740 a</td>
<td>3.920 a</td>
</tr>
<tr>
<td>Mentoring</td>
<td>4.740 a</td>
<td>4.730 a</td>
</tr>
<tr>
<td>Salary</td>
<td>30,520.83</td>
<td>29,333.33</td>
</tr>
</tbody>
</table>

Scales for competence, hireability, and mentoring range from 1 to 7, with higher numbers reflecting a greater extent of each variable. The scale for salary conferral ranges from $15,000 to $50,000. Means with different subscripts within each row differ significantly (P < 0.05). Effect sizes (Cohen’s d) represent target student gender differences (no faculty gender differences were significant, all P > 0.14). Positive effect sizes favor male students. Conventional small, medium, and large effect sizes for d are 0.20, 0.50, and 0.80, respectively (51). Female student condition = 63, Male student condition = 64. **P < 0.001.

Fig. 2. Salary conferral by student gender condition (collapsed across faculty gender). The student gender difference is significant (P < 0.01). The scale ranges from $15,000 to $50,000. Error bars represent SEs. nMale student condition = 63, nFemale student condition = 64.
Finally, using a previously validated scale, we also measured how much faculty participants liked the student (see SI Materials and Methods). In keeping with a large body of literature (15), faculty participants reported liking the female (mean = 4.35, SD = 0.93) more than the male student [mean = 3.91, SD = 1.08],  t(125) = −2.44, P < 0.05]. However, consistent with this previous literature, liking the female student more than the male student did not translate into positive perceptions of her composite competence or material outcomes in the form of a job offer, an equitable salary, or valuable career mentoring. Moreover, only composite competence (and not likeability) helped to explain why the female student was less likely to be hired; in mediation analyses, student gender condition (β = −0.48, P < 0.001) remained a strong predictor of hireability along with likeability (β = 0.60, P < 0.001). These findings underscore the point that faculty participants did not exhibit outright hostility or dislike toward female students, but were instead affected by pervasive gender stereotypes, unintentionally downgrading the competence, hireability, salary, and mentoring of a female student compared with an identical male.

Discussion

The present study is unique in investigating subtle gender bias on the part of faculty in the biological and physical sciences. It therefore informs the debate on possible causes of the gender disparity in academic science by providing unique experimental evidence that science faculty of both genders exhibit bias against female undergraduates. As a controlled experiment, it fills a critical gap in the existing literature, which consisted only of experiments in other domains (with undergraduate students as participants) and correlational data that could not conclusively rule out the influence of other variables.

Our results revealed that both male and female faculty judged a female student to be less competent and less worthy of being hired than an identical male student, and also offered her a smaller starting salary and less career mentoring. Although the differences in ratings may be perceived as modest, the effect sizes were all moderate to large (d = 0.60–0.75). Thus, the current results suggest that subtle gender bias is important to address because it could translate into large real-world disadvantages in the judgment and treatment of female science students (39). Moreover, our mediation findings shed light on the processes responsible for this bias, suggesting that the female student was less likely to be hired than the male student because she was perceived as less competent. Additionally, moderation results indicated that faculty participants’ preexisting subtle bias against women undermined their perceptions and treatment of the female (but not the male) student, further suggesting that chronic subtle biases may harm women within academic science.

Use of a randomized controlled design and established practices from audit study methodology support the ecological validity and educational implications of our findings (SI Materials and Methods).

It is noteworthy that female faculty members were just as likely as their male colleagues to favor the male student. The fact that faculty members’ bias was independent of their gender, scientific discipline, age, and tenure status suggests that it is likely unintentional, generated from widespread cultural stereotypes rather than a conscious intention to harm women (17). Additionally, the fact that faculty participants reported liking the female more than the male student further underscores the point that our results likely do not reflect faculty members’ overt hostility toward women. Instead, despite expressing warmth toward emerging female scientists, faculty members of both genders appear to be affected by enduring cultural stereotypes about women’s lack of science competence that translate into biases in student evaluation and mentoring.

Our careful selection of expert participants revealed gender discrimination among existing science faculty members who interact with students on a regular basis (SI Materials and Methods: Subjects and Recruitment Strategy). This method allowed for a high degree of ecological validity and generalizability relative to an approach using nonexpert participants, such as other undergraduates or lay people unfamiliar with laboratory manager job requirements and academic science mentoring (i.e., the participants in much psychological research on gender discrimination). The results presented here reinforce those of Stemperies, Anders, and Ritzke (40), the only other experiment we know of that recruited faculty participants. Because this previous experiment also indicated bias within academic science, its results raised serious concerns about the potential for faculty bias within the biological and physical sciences, casting further doubt on assertions (based on correlational data) that such biases do not exist (9–11).

In the Steinerpries et al. experiment, psychologists were more likely to hire a psychology faculty job applicant when the applicant’s curriculum vitae was assigned a male (rather than female) name (40). This previous work invited a study that would extend the findings to faculty in the biological and physical sciences and to reactions to undergraduates, whose competence was not already fairly established by accomplishments associated with the advanced career status of the faculty target group of the previous study. By providing this unique investigation of faculty bias against female students in biological and physical sciences, the present study extends past work to a critical early career stage, and to fields where women’s underrepresentation remains stark (2–4).

Indeed, our findings raise concerns about the extent to which negative predoctoral experiences may shape women’s subsequent decisions about persistence and career specialization. Following conventions established in classic experimental studies to create enough ambiguity to leave room for potentially biased responses (20, 23), the student applicants in the present research were described as qualified to succeed in academic science (i.e., having coauthored a publication after obtaining 2 y of research experience), but not irrebuttable excellent. As such, they represented a majority of aspiring scientists, and were precisely the type of students most affected by faculty judgments and mentoring (see SI Materials and Methods for more discussion). Our results raise the possibility that not only do such women encounter biased judgments of their competence and hireability, but also receive less faculty encouragement and financial rewards than identical male counterparts. Because most students depend on feedback from their environments to calibrate their own worth (41), faculty’s assessments of students’ competence likely contribute to students’ self-efficacy and goal setting as scientists,
which may influence decisions much later in their careers. Likewise, inasmuch as the advice and mentoring that students receive affect their ambitions and choices, it is significant that the faculty in this study were less inclined to mentor women than men. This finding raises the possibility that women may opt out of academic science careers in part because of diminished competence judgments, rewards, and mentoring received in the early years of the careers. In sum, the predoctoral years represent a window during which students’ experiences of faculty bias or encouragement are particularly likely to shape their persistence in academic science (30–33). Thus, the present study not only fills an important gap in the research literature, but also has critical implications for pressing social and educational issues associated with the gender disparity in science.

If women’s decisions to leave science fields when or before they reach the faculty level are influenced by unequal treatment by undergraduate advisors, then existing efforts to create more flexible work settings (42) or increase women’s identification with science (27) may not fully alleviate a critical underlying problem. Our results suggest that academic policies and mentoring interventions targeting undergraduate advisors could contribute to reducing the gender disparity. Future research should evaluate the efficacy of educating faculty and students about the existence and impact of bias within academic environments and approaches that have reduced racial bias among students (43). Educational efforts might address research on factors that attenuate gender bias in real-world settings, such as increasing women’s self-monitoring (44). Our results also point to the importance of establishing objective, transparent student evaluation and admissions criteria to guard against observers’ tendency to unintentionally use different standards when assessing women relative to men (45, 46). Without such actions, faculty bias against female undergraduates may continue to undermine meritocratic advancement, to the detriment of research and education.

Conclusions

The dearth of women within academic science reflects a significant wasted opportunity to benefit from the capabilities of our best potential scientists, whether male or female. Although women have begun to enter some science fields in greater numbers (5), their mere increased presence is not evidence of the absence of bias. Rather, some women may persist in academic science despite the damaging effects of unintended gender bias on the part of faculty. Similarly, it is not yet possible to conclude that the preferences for other fields and lifestyle choices (9–11) that lead many women to leave academic science (even after obtaining advanced degrees) are not themselves influenced by experiences of bias, at least to some degree. To the extent that faculty gender bias impedes women’s full participation in science, it may undercut not only academic meritocracy, but also the expansion of the scientific workforce needed for the next decade’s advancement of national competitiveness (1).

Materials and Methods

Participants. We recruited faculty participants from Biology, Chemistry, and Physics departments at three public and three private large, geographically diverse research-intensive universities in the United States, strategically selected for their representative characteristics (see SI Materials and Methods for more information on department selection). The demographics of the participating departments correspond to both the averages for the selected departments and faculty at all United States research-intensive institutions, meeting the criteria for generalizability even from nonrandom samples (see SI Materials and Methods for more information on recruitment strategy and participant characteristics). Indeed, we were particularly careful to obtain a sample representative of the underlying population, because many past studies have demonstrated that when this is the case, respondents and nonrespondents typically do not differ on demographic characteristics and responses to focal variables (47).

Additionally, in keeping with recommended practices, we conducted an a priori power analysis before beginning data collection to determine the optimal sample size needed to detect effects without biasing results toward obtaining significance (SI Materials and Methods: Subjects and Recruitment Strategy) (48). Thus, although our sample size may appear small to some readers, it is important to note that we obtained the necessary power and representativeness to generalize from our results while purposefully avoiding an unnecessarily large sample that could have biased our results toward a false-positive type I error (48).

Procedure. Participants were asked to provide feedback on the materials of an undergraduate science student who stated their intention to go on to graduate school, and who was evaluated as either a male student with a potential manager position. Of importance, participants believed they were evaluating a real student who would subsequently receive the faculty participants’ ratings as feedback to help their career development (see SI Materials and Methods for more information, and Fig. S1 for the full text of the cover story). Thus, the faculty participants’ ratings were associated with definite consequences.

Following established practices, the laboratory manager application was designed to reflect high but slightly ambiguous competence, allowing for variability in participant responses (20, 23). In addition, a promising but still nascent applicant is precisely the type of student whose persistence in academic science is most likely to be affected by faculty support or discouragement (30–33), rendering faculty reactions to such a student of particular interest for the present purposes. The materials were developed in consultation with a panel of academic science researchers (who had extensive experience hiring and supervising student research assistants) to ensure that they would be perceived as realistic (SI Materials and Methods). Results of a funneled debriefing (49) indicated that this was successful; no participant reported suspicions that the target was not an actual student who would receive their evaluation.

Participants were randomly assigned to one of two student gender conditions: application materials were attributed to either a male student (John, n = 63), or a female student (Jennifer, n = 64), two names that have been pretested as equivalent in likability and recognizeability (50). Thus, each participant saw only one set of materials, from either the male or female applicant (see Fig. S2 for the full text of the laboratory manager application and SI Method and Materials for more information on all materials). Because all other information was held constant between conditions, any differences in the participants’ responses were attributable to the gender of the student.

Using validated scales, participants rated student competence, their own likelihood of hiring the student, selected an annual starting salary for the student, indicated how much career mentoring they would provide to such a student, and completed the Modern Sexism Scale. Using validated scales, participants rated student competence, their own likelihood of hiring the student, selected an annual starting salary for the student, and completed the Modern Sexism Scale.

ACKNOWLEDGMENTS. We thank faculty members from six anonymous universities for their involvement as participants; and Jessamina Blum, John Cronnick, Jennifer Frederick, Jaime Napier, Jojanneke van der Toorn, Tiffany Tsang, Tessa West, James Young, and two anonymous reviewers for valuable input. This research was supported by a grant from the Howard Hughes Medical Institute Professors Program (to J.H.).


