SCIENTIFIC COMMUNITY

The gendered nature of authorship

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Authorship is the primary form of symbolic capital in science. Despite this, authorship is rife with injustice and malpractice, with women expressing concerns regarding the fair attribution of credit. Based on an international survey, we examine gendered practices in authorship communication, disagreement, and fairness. Our results demonstrate that women were more likely to experience authorship disagreements and experience them more often. Their contributions to research papers were more often devalued by both men and women. Women were more likely to discuss authorship with coauthors at the beginning of the project, whereas men were more likely to determine authorship unilaterally at the end. Women perceived that they received less credit than deserved, while men reported the opposite. This devaluation of women's work in science creates cumulative disadvantages in scientific careers. Open discussion regarding power dynamics related to gender is necessary to develop more equitable distribution of credit for scientific labor.

INTRODUCTION

Science has a hard time retaining women. Despite higher rates of matriculation, women are not advancing through the academic career path at the same rate as men. Social factors affect attrition rates in science, as in other sectors of the economy. Harrowing statistics on sexual assault and harassment demonstrate that academe does not provide a safe climate to all scientists (*1*). For women who remain in science, a steep hill awaits: There is evidence of gender bias in hiring (*2*), earnings (*3*), funding (*4*), and recognition by means of prestigious awards (*5*). Women are also underrepresented in scientific production generally (*6*) and in dominant author positions specifically (*7*) and do not receive equal treatment in peer review (*8*, *9*). These disparities are often correlated and mutually reinforcing, contributing to the Matilda effect by which women's academic work is more likely to be unrecognized and undervalued (*10*). Since scientific authorship in scholarly publications is a central mechanism to distribute credit for research, it has an important determinant in career progression (*11*, *12*) in which publications and subsequent citations serve as symbolic capital in the scientific community (*13*). Understanding the mechanisms underlying differential production is essential to address inequities in science (*14*).

While there is clear consensus regarding the importance of authorship as a marker of both credit and responsibility (*15*–*17*), there is considerable ambiguity as to how authors are chosen for inclusion in the byline of an article (a process we call author naming), as well as where they appear in the author list (author ordering) (*18*). Authors appear on the byline of scholarly papers, largely without any acknowledgment of the value and extent of their contribution. Although authorship is generally linked to the notion of "substantial contribution" to a research manuscript, this notion remains vague and open to interpretation. To address this problem, several fields have adopted tacit authorship ordering practices. For instance, first and last authors serve as dominant positions in most disciplines: First authors are those deemed to have contributed the most work, and last authors are typically senior positions, associated with the contribution of resources and design (*19*). Middle authors tend to perform technical work, a role with which women are disproportionately associated (*20*). Alternative models—such as "equal contribution" of more than one individual or alphabetical order—are present in some fields but remain much less prominent in science (*21*).

Science is a self-regulating system that is dependent on trust and collective adoption of ethical practices (*22*). The rise in the number of authors per paper (*23*) and ambiguity surrounding authorship has given rise to serious concerns about the ethical aspects of authorship (*24*–*26*) and the degree to which fairness is observed (*27*). Despite the creation of guidelines (*28*, *29*), authorship practices continue to be largely implicit and reproduce many of the biases observed in the research system (*2*, *30*). Women, in particular, have voiced concerns about unethical practices in authorship (*31*). Despite the importance of authorship for the accumulation of scientific capital and, therefore, for the reproduction of the gender bias in science, there is little evidence on gender differences regarding authorship attribution. Unobtrusive data, like bibliometrics, only provide counts of the authors on a published work. While this provides insights on resulting disparities in scholarly communication (*6*), it does not reveal the mechanisms behind authorship naming and ordering before publication. To gain a deeper understanding of gender differences in authorship practices, we surveyed more than 5500 scientists across the globe on their perceptions of and experiences with authorship naming and ordering.

RESULTS

Prevalence of authorship disagreements

Our results show that authorship disagreements are common in science: More than half (53.2%) of our survey respondents indicated that they had encountered authorship disagreements, either in author naming or author ordering (Fig. 1). Controlling for discipline and academic status, women are more likely than men to encounter author naming disputes (OR = 1.38, 95% confidence interval [CI] [1.22, 1.55]) and more likely than men to have disagreements in how authors were ordered (odds ratio [OR] = 1.25, 95% CI [1.11, 1.41]). In addition, women are more likely than men to express disappointment in their colleagues' failure to acknowledge their contributions (OR = 1.27, 95% CI [1.12, 1.43]). Gender differences in

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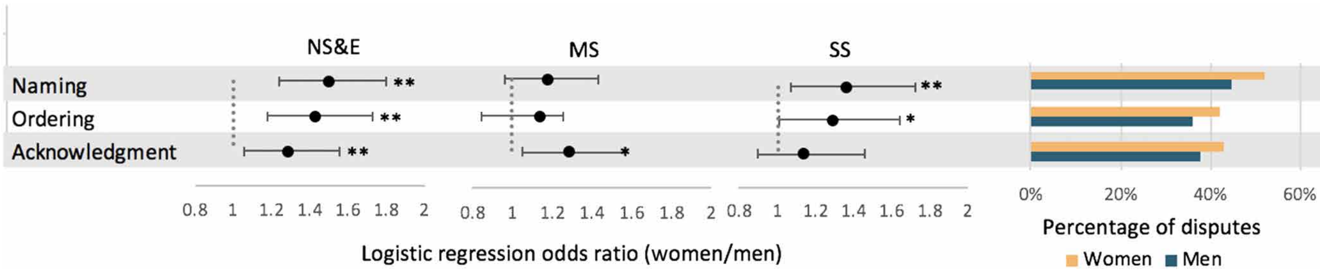

Fig. 1. Probability of encountering disputes. Disputes regarding author naming, ordering, and acknowledgment by discipline (logistic regression) and percentage of disputes by gender. Number of respondents varies as a function of the naming (*N* = 5572), ordering (*N* = 5574), and acknowledgment (*N* = 5529) questions. *P < 0.05 and **P < 0.01.

disagreements were most extreme in the natural sciences and engineering (NS&E), where women account for the lowest proportion of researchers. In this case, the odds of women reporting naming disagreement is 50% higher than that of men (OR = 1.50, 95% CI [1.24, 1.80]). Women were also more likely to report higher frequencies of authorship disagreements, for naming (OR = 1.35, 95% CI [1.14, 1.60] and ordering (OR = 1.35, 95% CI [1.12, 1.63]), respectively.

Irrespective of gender, different ways of valuing or measuring the importance of contributions were the most common cause for disagreements about authorship naming. When asked to assess the value of various types of contributions in their field of research, both genders agreed that "writing manuscript" and "data analysis" were the most important among all the categories (Fig. 2). Women rated all contributions higher than men, with one exception: technical work in medical science. Other differences were also observed across disciplines. For example, women in the medical sciences reported that "management and coordination" was of lower value, whereas "writing" and "study design" were valued the most. In the social sciences and professional fields (SS), women placed management and coordination and "technical work" as having lower importance. These contribution types strongly reflect gender roles in the laboratory in which women are disproportionately associated with technical work and men with study design and writing (*20*). This suggests a relationship between the value ascribed to a task and the gender associated, with tasks associated with women perceived of as having lower value by both men and women.

Communicating authorship

Communication is key to both preventing and managing disagreements. Researchers who discussed authorship issues—at any stage of a collaborative project—experienced lower frequencies of authorship disagreements than those who did not, irrespective of gender. There are, however, gendered differences as to whether and when authorship is discussed. As shown in Fig. 3, men are more likely (OR = 1.69, 95% CI [1.04, 2.78]) than women to report never having discussed authorship in NS&E. When they do discuss authorship, men are more likely (OR = 1.35, 95% CI [1.16, 1.57]) to do so when the manuscript is ready to be submitted; this is particularly true in the medical sciences and NS&E. Women, on the other hand, are more likely (OR = 1.17, 95% CI [1.03, 1.31]) to discuss authorship when the team is first formed, at the onset of the research project. This may prioritize certain types of scientific contributions that are more likely to play a dominant role at the beginning and end of scientific projects.

Principal investigators (PIs) are key deciders of authorship distribution: 49.5% of our respondents indicated that PIs would finalize the author list after consultation with the main contributors. In comparison, men were more likely (OR = 1.24, 95% CI [1.06, 1.45]) to report that they would decide on authorship without team consultation, particularly in the social sciences and in NS&E (see fig. S1). Overall, men seem to have a more authoritarian communication style by determining authorship with a small group at the end. Conversely, women tend to be more democratic and seek the agreement of a larger group at the beginning of the research process.

Furthermore, women reported being less likely (OR = 0.86, 95% CI [0.78, 0.96]) to feel like that they can openly and comfortably discuss authorship issues with members of their research teams. This pattern is predominant in SS and NS&E, where women are less likely (OR = 0.77, 95% CI [0.62, 0.97] and [0.66, 090], respectively) to feel that they can openly and comfortably discuss authorship issues. Given that men are predominantly PIs and have a tendency to discuss authorship only at the end with a select group of individuals, it is not unexpected that women feel excluded from this process, especially in larger teams.

Consequences of disagreements

Authorship disagreements tend to have a chilling effect on future collaboration. As shown in Fig. 4, both men and women reported "limiting further collaboration" as the most common result of a disagreement. In NS&E, women were more likely to observe hostility as a consequence of naming disagreements (OR = 1.34, 95% CI [1.10, 1.63]) and ordering disagreements (OR = 1.26, 95% CI [1.01, 1.58]). In SS, women were also more likely to observe hostility (OR = 1.54, 95% CI [1.16, 2.05]) as a result of naming disagreements.

When looking at all disciplines combined, we found that women were more likely (OR = 1.18, 95% CI [1.02, 1.37]) to observe hostility in response to ordering disagreements, while men were more likely (OR = 2.26, 95% CI [1.37, 3.75]) to observe "producing fraudulent research to compete with or undermine the results of a colleague" as a consequence to ordering disagreements. This was particularly true in the medical sciences (see fig. S2), where men are more likely (OR = 2.86, 95% CI [1.24, 6.76]) to observe fraud as a result of an ordering disagreement. In NS&E, men were more likely (OR = 1.96, 95% CI [1.02, 3.75]) to report that they have engaged in undermining the work of colleagues during meetings or talks as retribution for ordering disputes, whereas women were more likely (OR = 1.31, 95% CI [1.05, 1.65]) to report limiting future collaborations. These results are consistent with the findings of a higher prevalence of men in misconduct (*27*) and the more limited scientific networks of women (*6*). Although observing problematic behavior does not necessarily

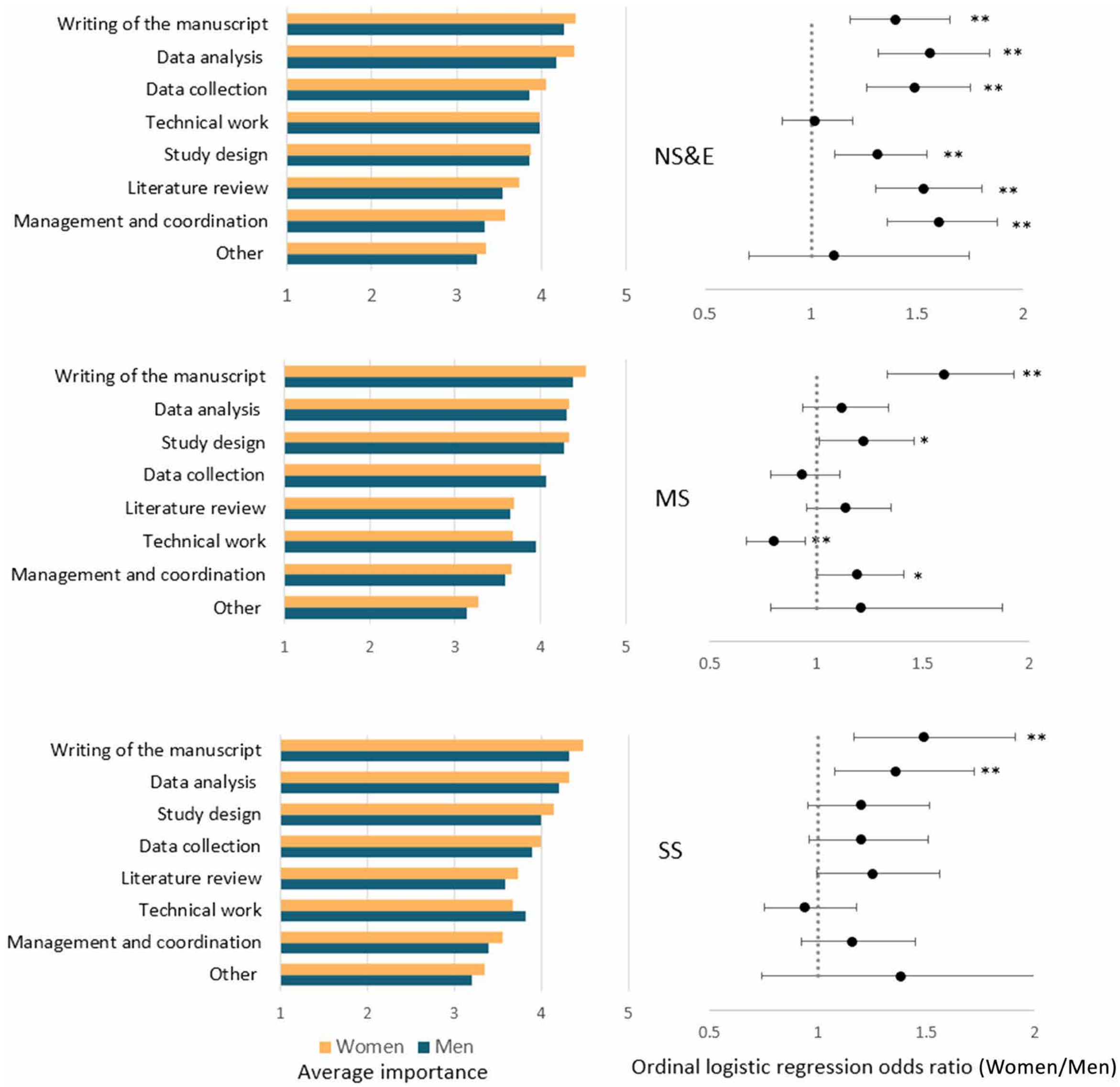

Fig. 2. Mean importance of contributions to a piece of research by discipline. Scaled from 1 to 5, "not important at all" to "extremely important." Number of observations by discipline: NS&E ($N = 2629$), MS ($N = 1781$), and SS ($N = 1068$). Ordinal logistic regression was conducted separately for each discipline with rank controlled in the model. *$P < 0.05$ and **$P < 0.01$.

result in the engagement of misbehavior, its recurrence and possible tolerance may serve to normalize problematic behavior in science while isolating women from academic networks.

Fairness in authorship

Authorship disputes are often associated with the (un)fair recognition of scientific contributions. When asked explicitly about fairness (fig. S3), women were more likely (CU = 1.14, 95% CI [1.03, 1.28]) to claim that they distributed authorship in a fair manner and their colleagues were unfair in their practices (CU = 1.12, 95% CI [1.01, 1.24]). Women also claimed that they received less credit than they deserved. Men respondents, on the other hand, were more likely (CU = 1.33, 95% CI [1.19, 1.48]) to state that they received more credit than they deserved.

Respondents were asked which author on the byline—first, last, or all—receives or should receive the most recognition (fig. S4). Both men and women agreed that first authors are those who receive the greatest recognition for their work in collaborative publications. Overall, it is more common for men (CU = 1.48, 95% CI [1.22, 1.80]) to report that all authors receive recognition compared with the first author receiving the greatest recognition. In NS&E, however, women are more likely (CU = 1.59, 95% CI [1.10, 2.29]) than men to report that the last author receives the most recognition as compared with the first author being recognized the most. Among those people who reported that the first author typically received the most recognition, women were more likely (OR = 1.23, 95% CI [1.04, 1.45]) to report that all authors should receive more credit for authorship. The gap in recognition differed on the basis of gender: Women were

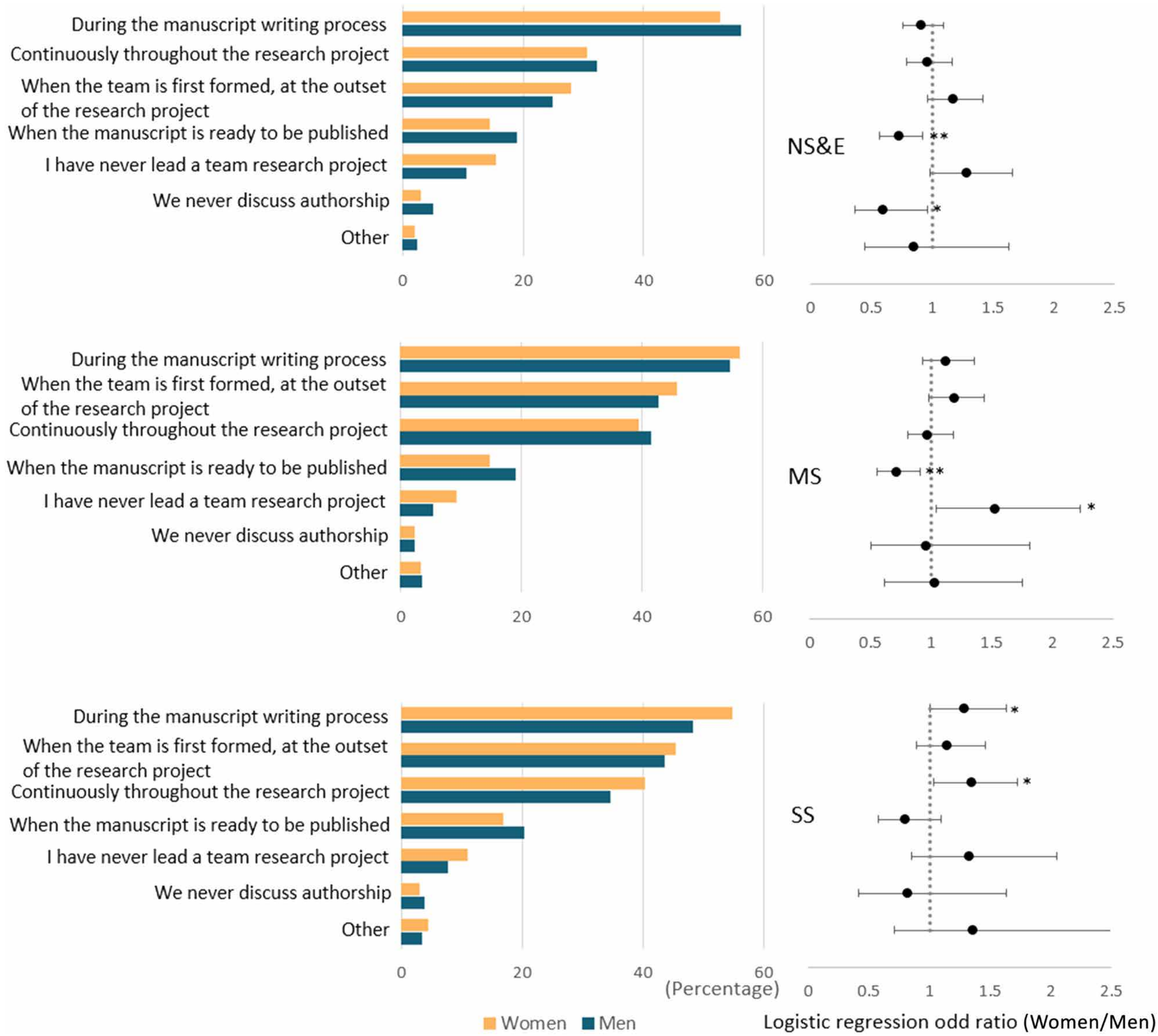

Fig. 3. Timing of authorship discussion. When you are leading a team research project, when do you discuss authorship? (Select all that apply.) Number of observations by discipline: NS&E (*N* = 2678), MS (*N* = 1800), and SS (*N* = 1097). **P* < 0.05 and ***P* < 0.01.

more likely (OR = 1.21, 95% CI [1.08, 1.36]) to report a gap between who is recognized and who should be; this suggests a dissatisfaction with the status quo. Disagreements may be more prevalent for women because they perceive the system as not recognizing those it should.

Constructive dialogue could provide greater clarity regarding authorship practices and address concern about fairness. Authorship practices vary strongly across disciplines, and some disciplines—such as those of the medical and NS&E—are more likely to have clear guidelines in attribution and naming than others (*15*, *17*). In the social sciences (fig. S5), "confusion and lack of clarity" as well as variation between team standards and journal standards are cited as vital reasons for ordering disagreements. Women were more likely to rely on guidelines (OR = 1.19, 95% CI [1.05, 1.35]) and to express larger concerns (OR = 1.23, 95% CI [1.11, 1.36]) when there were no guidelines or deviations between authorship practices and journal guidelines.

DISCUSSION

As author lists increasingly exceed hundreds and even thousands of authors (*23*), traditional forms of authorship lose their ability to demonstrate contribution. Disagreements may therefore arise simply because the two conventional anchors of prestige—first and last authorship—no longer suffice to credit contributions in an era of increasingly large collaborative teams. Many journals and publishers have therefore adopted contributorship statements, wherein scientists are not obliquely associated with a scientific product, but their contributions are clearly delineated (*32*). These initiatives serve to standardize authorship and bring heightened transparency and accountability to the authorship process (*33*). One example is CRediT, a 14-part taxonomy for authorship that has now been adopted by more than 120 journals (*28*). Such modes may not by themselves ensure equity—as contributions are assigned to those who have

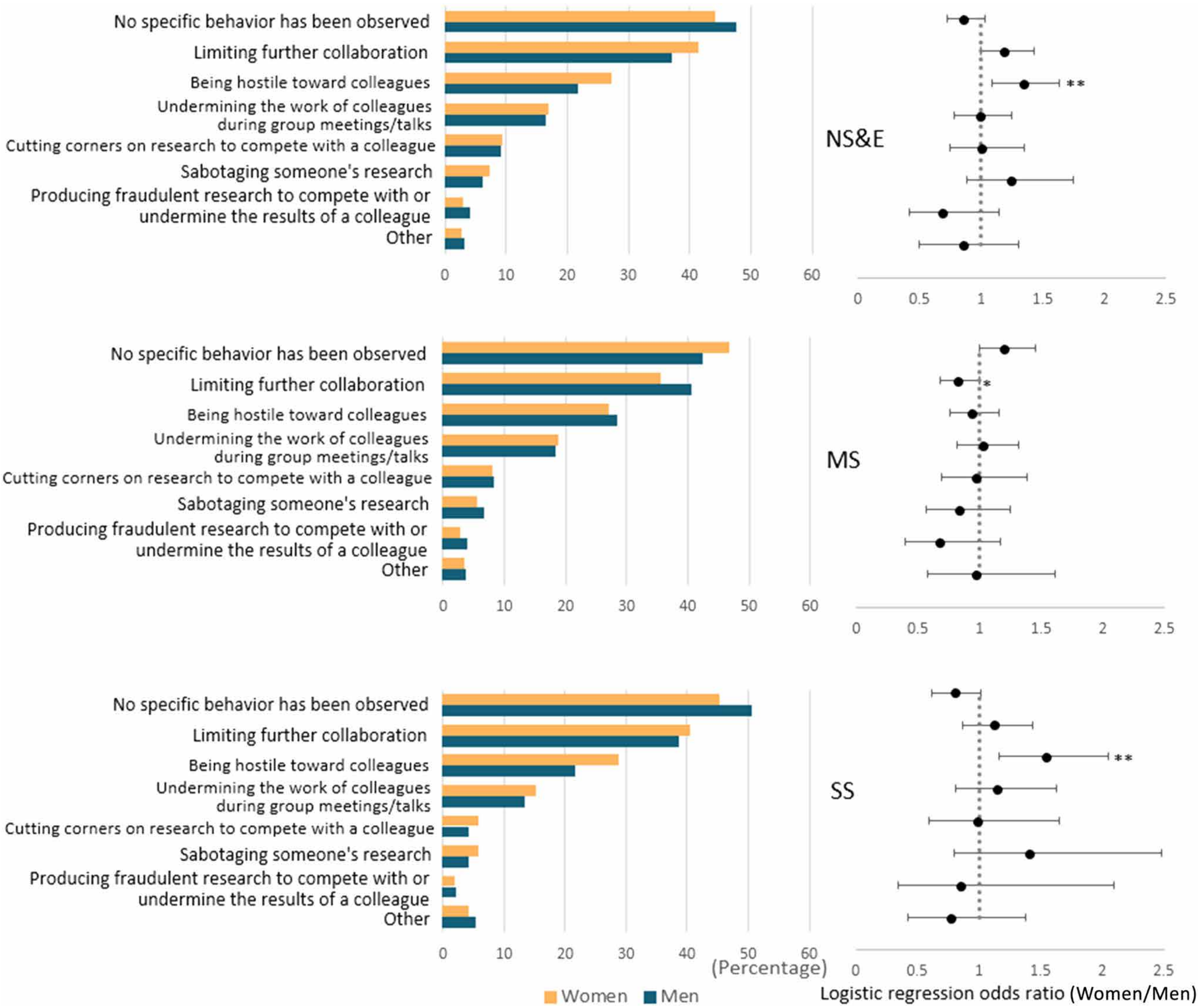

Fig. 4. Consequence of naming disputes. Have you observed any of the following behaviors from scholars as a result of an authorship naming disagreement? (Select all that apply.) Number of observations by discipline: NS&E ($N = 2678$), MS ($N = 1800$), and SS ($N = 1097$). *$P < 0.05$ and **$P < 0.01$.

made it to the authors' list—but they allow us to compare and contrast various practices to further understand inequity and mitigate negative impacts on a scientist's career progression. Journals may also want to instigate consensus attribution practices, which ask all authors to state their own contribution, rather than relying solely on the assignation by a corresponding author. This may reveal inequities that could be addressed before publication.

Scientific societies and universities are also in prime positions to develop guidelines around the distribution of authorship. Societies can articulate guidelines in ways that are sensitive to the disciplinary differences in scientific practices. Universities can ensure ethics training and oversight of funding. Increased standardization—and enforcement of this standardization—may serve to mitigate the prevalence of disagreements. Universities typically have processes for reporting scientific misconduct; however, authorship is not always included in the definition of misconduct. There should be more avenues for graduate students and postdoctoral workers to communicate authorship concerns to advocates within the university system. This may be particularly effective at reducing the effect of gender on disputes, given that women report the lack of clarity and discrepancy between guidelines and practice as chief concerns.

However, transparency is only one element in achieving equity; power dynamics are also critical. The locus of power in decision-making is typically with senior researchers—typically men—who get to determine whether transparency and open communication with other authors are enhanced throughout the process. Men seem to favor a more hierarchical construct of laboratory structure, demonstrated in previous ethnographies (*34*). Conversely, women seem to prefer more inclusive arrangements that allow broader participation in decision-making about authorship and a more representative recognition of scholarly contributions. Acknowledgment of these gendered differences and increased dialogue in the distribution of authorship may serve to mitigate potential disputes within research teams. Individual PIs should reconsider their own practices and engage in wider communication about authorship within their laboratories.

Science exists in a social space with its own set of idiosyncratic norms (*13*, *35*). Unfortunately, these norms are generally implicit and disadvantage those who are not part of the dominant social groups. Notably, opaque authorship has understated gender inequities and consequently created a space where they can increase unchecked. Transparency in authorship, not unlike the effects of other forms of remuneration (*19*), is essential for achieving equity in scholarly communication. If authorship is to remain as the primary currency of academe, then we must innovate to ensure that the practices are fair and account for changes in the scholarly communication ecosystem.

MATERIALS AND METHODS

Survey procedure

Using the Web of Science database from Clarivate Analytics, we constructed a population of 3,487,882 researchers who published at least one collaboratively authored paper between 2011 and 2015 (tables S2 to S6). From this population, a sample of 103,296 researchers was drawn, to which a 42-question survey about authorship practices was sent in May 2016. A total of 8364 respondents began the questionnaire, and 6579 finished at least one question; however, the present analysis is restricted to the 5575 respondents in the natural sciences, medical sciences, engineering, SS who provided complete responses on all analytic variables (this excludes the 155 complete responses in arts and humanities, because of the low response rates for these fields). Previous analysis of this survey has been performed in (*18*, *31*). An analysis of the attrition failed to identify a common point of departure, suggesting individual variability in dropout rather than failed survey construction.

The responses by gender and discipline did not differ significantly from the sample; however, respondents were more likely to self-identify as women (36%), which is slightly higher than the proportion (30%) of women authorships in the Web of Science (*6*). There were slightly more early- (including student trainees) and mid-career scientists (~30% each) than late-career scientists (22%), which is also to be expected given the attrition rates in science. Nearly half of respondents were from the NS&E (48%), with a third coming from the biomedical sciences (MS), and around 20% from the SS. More details on the representativeness of the analytic sample can be found in the Supplementary Materials.

Statistical analysis

To explore the gendered difference in authorship practice, we used several regression analysis techniques. We performed logistic regression analysis to analyze the role of gender while controlling for possible confounding variables such as career stage. Because of the difference in authorship practices among disciplines, we performed regression analyses for each discipline separately.

Specific procedures and analysis methods vary by the scale of dependent variables, as well as the number of variable categories. Regression procedures used here include ordinal logistic regression, multinomial logistic regression, and multiple logistic regression. Ordinal logistic regressions were used for items with ordered options, and multinomial logistical regressions were used for items with unordered options. Multiple logistic regression was used when a dependent variable is categorical and binary, while multinomial logistic regression was used when the dependent variable was categorical and had more than two response options.

Limitations

Large-scale analyses often mask differences among smaller groups or individuals within the data. For example, although we aggregated NS&E disciplines, there are large differences in authorship practices within, e.g., biology as compared to mathematics. We can observe some of these differences in our data. For example, only 34% of women in mathematics reported authorship naming disputes, whereas 54% of women in biology observed disagreements. However, these percentages are based on only 14 women in mathematics. Therefore, studies focused on particular disciplines—acknowledging idiosyncratic cultures of authorship—are necessary to complement this large-scale approach. Studies may also want to investigate the role of the gendered composition of the scientific workforce and the extent of disagreement.

Furthermore, there are strong differences in gender equity across countries that may influence results. Our global analysis includes authors affiliated to 128 countries; however, 71 countries have fewer than 10 respondents. Of the 13 countries with more than 100 respondents, 10 are considered "very high" on the Gender Inequality Index prepared by the United Nations Development Programme, suggesting some degree of homogeneity among the most frequent respondents. However, future studies focused on country-level analyses—taking nationality and affiliation into account—would provide another lens on these data.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at https://science.org/doi/10.1126/sciadv.abe4639

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The gendered nature of authorship

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