

The Gender Gap in Scholarly Self-Promotion on Social Media

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This file contains all reviewer reports in order by version, followed by all author rebuttals in order by version.

Version 0:

Reviewer comments:

Reviewer #1

(Remarks to the Author)

This paper empirically reveals gender difference in self-promotion of scientific papers on Twitter, using a cross section of 539K research papers published in 2018 (which form the basis for about 2.4 million author-paper pairs to investigate rate of each pair being self-promoted by the author). It reports the existence of a gender gap in self-promotion of research articles on Twitter.

The paper is clearly written and is tapping into a novel and interesting dataset that I believe can lead to interesting papers. I appreciate the authors' careful work on linking author names on papers to Twitter users' names. I am also impressed by the authors' careful validation of gender determination of author names as well as their creative use of alternative data sources to help robust check their results.

However, I still have a number of concerns.

1. Why does it matter?

Overall, I feel that the authors need to motivate the research question better.

First, while it is useful to know about the gender gap in Twitter-based self-promotion, it is not surprising to find a gender gap on self-promotion behavior. It would be helpful if the authors can motivate your investigation more carefully such that this does not become another "gender gap" paper.

Second, gender issues aside, why does Twitter promotion of research papers matter in the first place? My reading of the literature on the relationship between social media promotion and academic citation is that there is mixed evidence and no clear conclusion that instances of social media (particular, Twitter) mention is positively linked to academic citation increase (which matters more for researchers' evaluation) (e.g., Haustein et al., 2014; Liu and Huang, 2022; Ortega, 2016). If it is the case that Twitter mention is not that important for bringing on further academic attention, then how is revelation of this particular gender gap in this paper important for our understanding of the gender inequality in science?

To be clear, the authors may have an argument that the question investigated in the paper is an important one, but the case has not yet been made very clear in the current draft.

2. Rare Event Concern

From Fig S1.A., it seems that twitter mention frequency for research papers is highly skewed. However, I cannot find anywhere in the paper that the authors report how many (or what fraction) of all the 539K papers in the sample have been Twitted at all. And since the key models are assessed at author-paper level, it is also important to report the fraction of author-paper dyad in the data that are non-zero in Twitter mention. If the fractions are too low (e.g., under 5-6%), it triggers rare event concerns and convention logistics models will yield biased estimates (see Gary King, 2001 for details; newer class of models also exist, such as penalized logit models).

3. Twitter's geographical coverage

I appreciate the authors' careful robustness tests with East-Asian names being excluded from analysis. This is helpful. However, the question remains how popular is Twitter among academics (or among the general population) across different regions in the world? For example, Statista reported Twitter being popular in U.S. and Japan. But for India, a nation with a population of 1.4 billion, Twitter user count is merely 26 million (<https://www.statista.com/statistics/242606/number-of-active->

twitter-users-in-selected-countries/), accounting for only 1.8% of population. Maybe the share of Indian-based author publications is small and thus the majority of the cases are in the U.S. If that is the case, it is important to be clear about where your argument applies (or not applies) geographically. And more importantly, is the geographical variation in Twitter use rate intertwined with gender issues in these different regions?

4. While it is helpful to control for authorship positions in the models, the concern is that authorship position interacts with other variables (e.g., affiliation ranking and author productivity) to jointly shape Twitter use outcome. In such cases, it is cleaner to provide robustness analysis that restricts the sample to only paper-author dyads where the authors are in last-author position for natural sciences (i.e., only comparing papers for the PIs), and where the authors are in the first-author position for social sciences. This helps make an apple-to-apple comparison of scientists in similar positions in a paper.

Format

5. You should avoid using abbreviated variable name extensively. For example, a lot of the variable names in Table S1 are abbreviated and readers would have to guess what you meant with each variable (e.g., I know “author_pub_count_cat” is about author publication count, but I don’t know how exactly you measure author publication count; how is affiliation rank measured?). Adding explanation for some of the variables will help if they are not straight-forward continuous.

Haustein, S., Peters, I., Sugimoto, C.R., Thelwall, M. and Larivière, V. (2014), Tweeting Biomedicine: An Analysis of Tweets and Citations in the Biomedical Literature. *J Assn Inf Sci Tec*, 65: 656-669. <https://doi.org/10.1002/asi.23101>

King, G. & Zeng, L. (2001) Logistic Regression in Rare Events Data. *Political Analysis*, 9: 137–163. <https://tinyurl.com/y463rgub>

Liu, C. & Huang, M. (2022). Exploring the relationships between altmetric counts and citations of papers in different academic fields based on co-occurrence analysis. *Scientometrics* (2022) 127:4939–4958. <https://doi.org/10.1007/s11192-022-04456-w13>

Ortega, J.L. (2016). To be or not to be on Twitter, and its relationship with the tweeting and citation of research papers. *Scientometrics* 109:1353–1364.

(Remarks on code availability)

Reviewer #2

(Remarks to the Author)

Referee report for NCOMMS-24-13075 The Gender Gap in Scholarly Self-Promotion on Social Media

The paper analyzes the tendency of male and female scholars to promote their research on Twitter, finding that women are significantly less likely to engage in self-promotion than men, even after controlling for a battery of factors. This gender disparity persists across different scientific disciplines and is pronounced among high-achieving women from prestigious institutions. The paper is well-written, and the empirical results are quite comprehensive. Here are a few comments and suggestions:

1. The paper appears to equate academic productivity with career stage by using the number of publications and citations as measures. Although these are correlated, I would recommend using a more standard proxy, such as the number of years since the first publication.

2. In similar vein, it would be beneficial to include more controls related to Twitter usage, beyond just the number of followers; for example, the year the account was created, average activity levels (tweets, retweets, likes), and the nature of the follower/following circle (whether it includes more academics, which might indicate whether the account is used more for private or scholarly purposes). Additionally, was the follower count measured at the time of self-promotion, or was the most current number used? If the latter, this introduces an endogeneity issue.

3. It would be intriguing to discover whether male authors are also more likely to self-promote older research, rather than just new publications. This strategy might be employed particularly when the research topic aligns with current societal interests.

4. Is it feasible to control for the timing of self-promotion relative to the initial popularity of the publication on Twitter (or mentions in other news outlet from Altmetric)? For instance, controlling for the number of mentions before the self-promotion occurred, and identifying which outlets (news agencies, institutions, another co-author, or academics) were responsible for these mentions.

5. Exploring field variations more extensively than just the four broad disciplines would be insightful. For example, the gender ratio disparity between fields within the social sciences, such as economics versus psychology (where economics shows greater female underrepresentation, see Chan and Torgler, 2020), could provide deeper insights.

6. While I appreciate the method of measuring the ‘return on self-promotion’ through the total number of tweet mentions, I am skeptical of its effectiveness as it might be confounded by other forms of promotion (e.g., by colleagues, institutions, or news outlets) that are not direct results of the authors’ self-promotion efforts. A more precise measure would examine if tweets that are self-promotional garner more retweets, likes, or shares, indicating higher engagement (see e.g., Chan, Bodiuaazman, Torgler, 2020).

7. Furthermore, if there is a gender-differential return on self-promotion, this creates a demand-induced supply scenario

(where females engaging in less self-promotion due to lower returns). It would be valuable to investigate more deeply whether this discrepancy persists after controlling for these lower returns.

8. A deeper investigation into the qualitative aspects of how self-promotion is conducted would also be beneficial. Did the authors simply share a link, or did they enhance their tweets with additional text, context, or hashtags? The quality of these promotions may significantly influence their effectiveness and reach.

9. Concerning Twitter name-matching, are female scientists more likely to use pseudonyms (possibly due to online harassment, as suggested)? This could underestimate the actual rate of self-promotion among females and, paradoxically, using a pseudonym could undermine the purpose of self-promotion. This aspect warrants further discussion.

References:

Chan, H. F., & Torgler, B. (2020). Gender differences in performance of top cited scientists by field and country. *Scientometrics*, 125(3), 2421-2447.

Chan, H. F., Bodiuzzman, S. M., & Torgler, B. (2020). The power of social cues in the battle for attention: Evidence from an online platform for scholarly commentary. *Journal of Informetrics*, 14(4), 101077.

(Remarks on code availability)

Reviewer #3

(Remarks to the Author)

Thank you to the authors for their important work. The results are clear and compelling, and the authors' methods are well suited to address their research questions. I am enthusiastic about this paper, though I believe it can be developed in several respects. I do not take issue with the data collection and methods (though see my comments on gender categorization), but moreso with fundamental assumptions of what the paper can and cannot tell us; the paper should be upfront with this and engage more deeply with these complexities. I see the paper as a first step in understanding the extent of self-promotional differences on social media and how we can alleviate them. The paper's limitations regarding intersectionality are particularly emblematic of other steps that must be taken in future investigations.

- First, It is important to mention the wider context in which Twitter/X sits within, and whether its values are misaligned with societal expectations for women's behavior. We are aware of the many ways that the platform aggrandizes sense of self-importance, combative behavior, machiavellianism, and low cognitive reflection - several papers in this journal have led our understanding in these respects. It is not a coincidence that the cultural construction of patriarchal masculinity has considerable overlap with the social/behavioral constructs that proliferate within the platform. In other words, Twitter is not a gender neutral "tabula rasa" social media platform - the culture that the app nurtures is gendered, meaning that it may be an "icy climate" for some individuals more than others. Please account for this in your introduction and discussion.

- While you are able to show that differences in self promotion cannot be explained by there simply being fewer women on Twitter, it is useful to consider what types of women are on twitter. This makes your results more compelling, as women who are on the platform already have some interest in online visibility and do not find Twitter to be culturally impoverished enough of a space to withdraw their participation from it entirely. This means that among women who have met the threshold of being interested in a platform that is inherently self-promotional, the gender gap still exists.

- Please include some type of quantification of the number of papers published in a given year overall compared to the number of papers that are mentioned on Altmetric in that same period. It would also be helpful, if at all possible, to provide numbers around overall gender differences in number of academics on twitter vs. those who are not - considering that you show "men are indeed more likely than comparable women to be active on Twitter." Providing some visualizations on this will drive home the context in which your analyses are situated, and will perhaps also provide a sense of scale.

- I'm aware that you cite your gender verification method as a limitation. This said, still please provide significantly more detail on how your model is accounting for racial and ethnic difference in gendered names. What confidence should we have that in comparing "the algorithm's inferences to an auxiliary dataset containing the self-reported gender of 432,888 physical scientists," this list is race representative? Presumably, this list of scientists would mirror known representational problems in science, of which the physical sciences is notorious. How many of the people on this list are women? How many have names that are not easily categorized using Western-centric naming conventions? This list should be available.

- How do you make sense of the growth in self-promotion gender differences? This is why it is vital to provide more context on the operation and culture of the platform you are studying, which has become gradually more entrenched in masculine norms and outwardly masculinist ownership (your data can of course not account for when the ownership change occurred).

- Is it possible that your effect of "authors with gender-neutral names self-promote less often than those with gender-distinct names" may be influenced by racially and ethnically differentiated norms around self-promotion? Are those with gender neutral names randomly distributed across race and ethnicity? How is this being disentangled?

- You mention "men's higher enthusiasm and greater returns for self-promotion, but you have not measured enthusiasm. It seems entirely likely that women may be enthusiastic but that several barriers keep this enthusiasm from translating into actual self-promotion on Twitter.

- There is room to develop your implications and practice section. You assume that it is women who should catch up to men's self promotion through institutions providing "provide training, dedicated time, and support." Is this not another non-promotional use of women's time? Should we endeavor for work to be featured on Twitter, or are there other, perhaps more creative ways to democratize how papers are shared and made visible without perpetuating existing hierarchies within the academy? How might hiring and tenure committees be made aware of the headwinds women face in self-promotion, and how men's opportunities and collaborations may indeed be shaped by self-promotion culture? I'd like to see much more substantive and creative thinking in this vein rather than the blanket assumption that all scholars should meet a culture that

is, by your own findings, set and maintained by men.

- There must be an acknowledgement in your limitations about race. The problem of self-promotion is certainly not just gendered, but is likely to also have racial components whereby people of color are more likely to underestimate the quality of their work and receive more backlash for self-promotion. White men are likely self-promoting more than some men of color. This paper is not able to shed light on this, and the reasons why this would be difficult and problematic to estimate (algorithmic categorization of race), should be acknowledged. But there is no doubt that you are studying an intersectional phenomenon that cannot be analyzed in its intersectional entirety.

(Remarks on code availability)

Code appears reproducible.

Version 1:

Reviewer comments:

Reviewer #1

(Remarks to the Author)

Thank you for your effort to address my questions and concerns raised in the earlier round of review. Again, I appreciate your empirical effort. I don't doubt the core result of your paper with regard to the existence of a gender gap in the tendency of self-promotion on Twitter (currently X). However, I don't believe that the motivational questions I raised in the previous round of review have been sufficiently addressed. Ultimately, the main challenge is still the "so what" question. As I noted in my previous referee report, the gender gap exists on many fronts in science and among scientists. Can the findings based on this paper inform policies for interventional measures that can reverse the gender gap with regard to important outcomes in science? Scientists' time and energy is constrained. Can we use the knowledge from this paper to persuade women scientists to increase their effort of self-promotion on Twitter or other social media platforms? The answer is ambiguous, particularly given your finding that return to self-promotional activities is not very much in favor of women.

The fraction of scientists who went on to Twitter to post messages is small, and the fraction among them who self-promote is even smaller. To what extent knowing any gender gap in this activity can improve overall gender inequity in science? This is at the core of my request for you to motivate your research paper more carefully. Unfortunately, I am not convinced that this issue has been resolved in this revision.

One other issue: the title and abstract seem to suggest that the results reported in the paper are about gender gap in self-promotion in Twitter. Yet, if I understand it correctly, most of the models of likelihood of self-promotion are estimated on the risk pool of scientists who have records on Twitter (Twitter adopters). This is not reflective of the real gender gap of social media self-promotion among the general population of scientists—to estimate that gap, you would need a different risk pool. This point has not been clearly stated in the paper and is thus somewhat misleading.

While propensity score matching helps resolve confounding issue (that the types of scientists who Twitted are different from the types of scientists who didn't), it is not a not reliable solution as you are relying on the assumption that observable variables can fully account for the confounding factors. Yet, this is a strong assumption to make.

(Remarks on code availability)

I have not installed the codes.

Reviewer #2

(Remarks to the Author)

The authors have provided detailed and thoughtful responses to my previous comments. They have provided extensive additional new analyses (particularly on career stage and field variations) which improve the manuscript. I appreciate their willingness to engage with most of the points raised and their transparency about the limitations in some cases. I believe the manuscript is much stronger as a result of these revisions, and I am satisfied with the overall responsiveness of the authors and recommend the revised version for publication.

Below is the assessment by my co-reviewer:

This paper presented valuable insights regarding the gender gap in scholarly self-promotion online, and the authors thoroughly addressed Reviewer 2's feedback. Where possible, they conducted additional analyses as recommended, which were sufficiently explained within the main paper and/or supplementary materials. Where it was not feasible to examine the questions raised by the reviewer, the authors provided valid justification as to why this was the case and articulated these additional limitations/extensions clearly in the paper's discussion.

(Remarks on code availability)

Reviewer #3

(Remarks to the Author)

Thank you to the authors for your hard work on this revision. For the sake of consistency I will stay within the remit of my original review. In general, I am satisfied with the authors' changes to the manuscript and I believe this paper is acceptable for publication. My thoughts on the importance of this matter and appreciation to the authors for bringing it to light remain.

I would like to mention, however, that I feel most of my comments have been addressed via lip-service rather than a deeper grappling with the meaning of women's self-promotion in an academic/social environment that privileges men and traditional masculine norms. You have addressed my comments by adding in language that is similar to my suggestions, but I was hoping for these threads to be reflected more in the overall tone and ethos. I have been discouraged by seeing, even in a paper about gender, an almost reflexive tendency to point towards women's behavior rather than problems with the culture women are situated within. I would aim to actively work against a tone in your introduction that seems to imply that women should be self-promoting more, rather than suggesting that men should potentially self-promote less and without exaggeration of their achievements (doesn't it also make sense that women self promote less if they have less to gain from it, as this paper's results suggest?) For example, thoughts like the following are offered without context: "A growing literature finds that women spend more time on non-promotable tasks, such as emotional support towards trainees and academic service." Because you don't interpret this, your reader may take away that women shouldn't be doing those non-promotable tasks and should be self-promoting more instead. Why not work to reframe some of these sentences in ways that show that men often do not do their fair share of non-promotable work, in order to create a sense of balance in this introduction? In fact, such non-promotable work is key to students' educational experience and the running of a department. This is the type of ethos change, rather than a simply language change, in which I would like to see a more comprehensive engagement. On this same note I wonder if it would be useful to mention that education opportunities on the gender gap in self-promotion would be specifically useful to online men in academia, who are the biggest stakeholders in upholding and potentially changing the current culture. Whether you need to address this feedback should be a matter of the editors' discretion.

(Remarks on code availability)

Code appears reproducible.

Version 2:

Reviewer comments:

Reviewer #1

(Remarks to the Author)

Dear Authors,

Thank you for addressing my concerns in the last round of the review.

First, I appreciate your clarification on the risk pool question. That's helpful.

Second, unfortunately, I don't think the question I raised regarding the motivation (or purpose) of the paper has been resolved satisfactorily. I appreciate your effort of motivating your question with additional text, but ultimately, I think this is not something that can be addressed with an additional paragraph of text. There is a lot more to do in order to turn the paper beyond just a simple report of descriptive facts--some redesign is needed, which will call for non-trivial work.

In sum, my assessment of your paper still comes down to the following. (A) The main contribution of the paper is that you have reported empirically a pattern of gender gap in self-promotional behavior of scientists in social media. I am convinced by the pattern you have shown. (B) But is this revealed pattern sufficiently important to deserve the valuable real estate of Nature Communications? I personally am not persuaded so. This is my own assessment and I may have been too harsh on you. Ultimately, for me, the motivation for publishing empirical patterns as those you have revealed in the paper is that the revelation can help inform policy making in the future to resolve important problems in your target population of scientists (in this case, gender inequity in science). Against this bar, I am not sold. But ultimately, I respect the Editor's opinion on this front.

(Remarks on code availability)

Reviewer #4

(Remarks to the Author)

I co-reviewed this manuscript in the second round with a senior reviewer who provided the listed reports. This is part of the Nature Communications initiative to facilitate training in peer review and to provide appropriate recognition for Early Career Researchers who co-review manuscripts.

(Remarks on code availability)

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Re: NCOMMS-24-13075

Dear Editor and Reviewers,

Thank you for your careful engagement with our manuscript and thoughtful suggestions for improvement. We have revised the paper in light of these insightful comments and believe it has been substantially improved. The key revisions include:

1. We improved the motivation of our research questions, including a better and more up-to-date literature review of the link between online attention and academic outcomes like citations. We also added references to the current debate regarding women's participation in online platforms, including the potentially reduced barriers online compared to offline contexts, uncontrolled harassment, and likely misalignment between cultural norms on Twitter/X and gendered expectations of women's behavior.
2. We conducted all requested robustness checks and additional analyses, including (i) using methods suited for rare events, (ii) comparing authors with the same authorship positions in the same field, (iii) measuring career stage as the number of years since first publication, and (iv) testing more fine grained subject areas.
3. We added a linguistic analysis of self-promotional tweets, which shows that men indeed use more promotional words such as "unprecedented" and "remarkable" than women.
4. We provided details and limitations of our measures, such as the follower count, variables related to Twitter usage, and quantifying return as the total number of mentions. We also acknowledged the unexplored yet key role of intersectionality in self-promotion.
5. We clarified the scale and coverage of our data in terms of the overlap between the Altmetric and the Microsoft Academic Graph databases, and why the data from the Institute of Physics Publishing that we used to validate the gender classifier with self-reported gender information cannot be shared publicly.
6. We enriched the interpretation of our findings with implications for scholarly evaluation in academia, highlighting that potential solutions aiming to close the gender gap in self-promotion should focus on "fixing the institutions" instead of "fixing the women".

All new analyses are quite consistent with our initial finding that women self-promote their research much less often than men doing comparable research. Our "Point-By-Point Discussion" responds to each Reviewer's comment with additional details.

We appreciate your time and consideration and look forward to hearing from you.

Best regards,

Hao Peng, Misha Teplitskiy, Daniel M. Romero, Emőke-Ágnes Horvát

1 Point-By-Point Discussion

We thank the Reviewers for their thorough comments, constructive feedback, and great ideas. The revised manuscript addresses all of the raised concerns.

1.1 Response to Reviewer 1

Comment 1.1

This paper empirically reveals gender difference in self-promotion of scientific papers on Twitter, using a cross section of 539K research papers published in 2018 (which form the basis for about 2.4 million author-paper pairs to investigate rate of each pair being self-promoted by the author). It reports the existence of a gender gap in self-promotion of research articles on Twitter.

The paper is clearly written and is tapping into a novel and interesting dataset that I believe can lead to interesting papers. I appreciate the authors' careful work on linking author names on papers to Twitter users' names. I am also impressed by the authors' careful validation of gender determination of author names as well as their creative use of alternative data sources to help robust check their results.

Response

We thank Reviewer 1 for the positive feedback and the many helpful comments that follow. To clarify, unlike an earlier version of this study that focused on 2018 papers, the current paper examines 2.8 million research papers published between 2013 and 2018 that are indexed in the Altmetric database. 72.2% of these papers have received at least one mention on Twitter.

Comment 1.2

However, I still have a number of concerns.

1. Why does it matter? Overall, I feel that the authors need to motivate the research question better.

First, while it is useful to know about the gender gap in Twitter-based self-promotion, it is not surprising to find a gender gap on self-promotion behavior. It would be helpful if the authors can motivate your investigation more carefully such that this does not become another "gender gap" paper.

Response

We agree that our motivation needed improvement, and we have updated it in the revision. As the updated paper clarifies, our study explores critical new territory in two ways.

(1) Changing patterns: The classic work on gender gaps in self-promotion was published nearly 30-40 years ago. More recently, work in the field challenges whether the gender gap in speaking up for oneself exists, for instance, in salary negotiations (Kray et al., 2024).

(2) Online vs. offline trends: Some of the recent literature proposed that online spaces might help equalize the playing field for women (Durbin et al., 2020; Kang, 2022). Other research debates this, finding a gender gap in the online visibility of scholars' work (Vásárhelyi et al., 2021). Most importantly, none of these work uncovers which factors might be associated with gendered research dissemination on online platforms. While self-promotion has been examined as a driver of visibility in offline contexts, its role in online platforms has not been explored so far.

Comment 1.3

Second, gender issues aside, why does Twitter promotion of research papers matter in the first place? My reading of the literature on the relationship between social media promotion and academic citation is that there is mixed evidence and no clear conclusion that instances of social media (particular, Twitter) mention is positively linked to academic citation increase (which matters more for researchers' evaluation) (e.g., Haustein et al., 2014; Liu and Huang, 2022; Ortega, 2016). If it is the case that Twitter mention is not that important for bringing on further academic attention, then how is revelation of this particular gender gap in this paper important for our understanding of the gender inequality in science?

To be clear, the authors may have an argument that the question investigated in the paper is an important one, but the case has not yet been made very clear in the current draft.

Response

We agree that Twitter promotion in isolation is of dubious importance if it does not affect other, arguably more consequential outcomes like citations or media coverage. The evidence on this topic has been steadily accumulating. In addition to the papers you mention, which we added to our paper, there are now several more articles that investigate the link between online mentions and citations, such as Hayon et al. (2019); Jeong et al. (2019); Dehdarirad (2020); Klar et al. (2020); Liakos et al. (2021); Ladeiras-Lopes et al. (2022); Peres et al. (2022); Chapman et al. (2022); Vászrhelyi and Horvát (2023); Chan et al. (2023); Qiu et al. (2024); Stephen and Stahlschmidt (2024). Crucially, some of these newer papers have more robust designs for inferring causality, including randomized controlled trials (RCTs).

For example, Liakos et al. finds that social media enhances the exposure of peer-reviewed medical papers using matching techniques (Liakos et al., 2021). Chan et al. developed an instrumental variable to show that one tweet can lead to 16–25% more citations (Chan et al., 2023). Recent studies using RCTs find a similar association between Altmetric score and citations (Peres et al., 2022), and Twitter promotion is even linked to job market success (Qiu et al., 2024).

Moreover, a recent meta-analysis of 914 correlation coefficients reported in 111 studies of 13 altmetric indicators showed that the Altmetric-citation association is most strongly observed on Twitter (Stephen and Stahlschmidt, 2024).

Each of the pieces of evidence above has its own limitations, and we do not want to claim complete certainty. However, we think it is appropriate to interpret the available evidence as showing that many researchers use social media platforms like Twitter/X to search for or discover academic papers, leading to an association between Twitter engagement/attention and academic outcomes like citations.

Furthermore, it is also plausible, but understudied, that Twitter attention increases other consequential outcomes like media coverage (Peng et al., 2024) and policy take-up (Yin et al., 2021), which can then contribute to prevalent alternative measures for scholarly evaluation Sugimoto et al. (2017); Kwok (2013); Sopinka et al. (2020). We have updated our reference list to include these recent studies.

Comment 1.4

2. Rare Event Concern From Fig S1.A., it seems that twitter mention frequency for research papers is highly skewed. However, I cannot find anywhere in the paper that the authors report how many (or what fraction) of all the 539K papers in the sample have been Twitted at all. And since the key models are assessed at author-paper level, it is also important to report the fraction of author-paper dyad in the data that are non-zero in Twitter mention. If the fractions are too low (e.g., under 5-6%), it triggers rare event concerns and convention logistics models will yield biased estimates (see Gary King, 2001 for details; newer class of models also exist, such as penalized logit models).

Response

We appreciate the Reviewer's attention to detail. In our data, 72.2% papers have received at least one mention on Twitter. This fraction is similar among author-paper dyads (74.6%). We added these statistics to the Materials and Methods section of the paper.

However, the percentage of self-promotion observations in our data is 4.2%. To address the rare event concern, we ran a penalized logit model using ridge regression that shrinks the coefficients of the less contributive variables toward zero. Table R1, displayed below, shows that the result is consistent with our original finding.

Table R1: Coefficients of all variables in a penalized logit model that predicts **whether the author self-promoted the paper**. The model is fitted to 11,396,752 observations. *Note that this type of regression does not produce significance indicators such as p-values. Instead, a close-to-zero coefficient indicates a less contributing variable or insignificance.* The woman coefficient is negative and far from zero, indicating that women are indeed less likely to self-promote their papers on Twitter than comparable men. Coefficients for 26 Scopus Subject Areas are omitted here for clarity.

	Dependent variable: Self-promotion = True
Woman	-0.291
Authorship first position	0.356
Authorship middle position	-0.556
Authorship solo author	0.696
Affiliation rank	-0.048
Affiliation location international	0.080
Author previous num. of publications	0.097
Author previous num. of publications (squared)	-0.008
Author log citations	0.008
Publication year 2014	0.020
Publication year 2015	0.338
Publication year 2016	0.576
Publication year 2017	0.919
Publication year 2018	1.275
Number of authors	-0.001
Journal impact factor	0.034
Intercept	-3.692
Observations	11,396,752

Comment 1.5

3. Twitter’s geographical coverage I appreciate the authors’ careful robustness tests with East-Asian names being excluded from analysis. This is helpful. However, the question remains how popular is Twitter among academics (or among the general population) across different regions in the world? For example, Statista reported Twitter being popular in U.S. and Japan. But for India, a nation with a population of 1.4 billion, Twitter user count is merely 26 million (<https://www.statista.com/statistics/242606/number-of-active-twitter-users-in-selected-countries/>), accounting for only 1.8% of population. Maybe the share of Indian-based author publications is small and thus the majority of the cases are in the U.S. If that is the case, it is important to be clear about where your argument applies (or not applies) geographically. And more importantly, is the geographical variation in Twitter use rate intertwined with gender issues in these different regions?

Response

As per your suggestion, we provide geographical distribution statistics of our data in Table R2. We inferred the country of affiliation based on institutions’ longitude and latitude provided in the Microsoft Academic Graph data. Western countries such as the United States, United Kingdom, and Germany account for 49% of all paper-author observations in our data, and authors affiliated with these countries are much more likely to be active on Twitter than those from East Asian countries including China and Japan. Thus, our finding is more applicable to institutions in Western countries. We have added this limitation to the discussion.

Table R2: Top 10 countries based on the number of paper-author dyads. Three Western countries including the United States, United Kingdom, and Germany account for 49% of our observations.

Country of affiliation	Number of observations
United States	3,964,712
United Kingdom	1,008,211
Germany	614,149
Australia	575,758
China	457,319
Canada	449,088
Japan	400,034
France	387,454
Italy	359,034
Netherlands	313,734

Comment 1.6

4. While it is helpful to control for authorship positions in the models, the concern is that authorship position interacts with other variables (e.g., affiliation ranking and author productivity) to jointly shape Twitter use outcome. In such cases, it is cleaner to provide robustness analysis that restricts the sample to only paper-author dyads where the authors are in last-author position for natural sciences (i.e., only comparing papers for the PIs), and where the authors are in the first-author position for social sciences. This helps make an apple-to-apple comparison of scientists in similar positions in a paper.

Response

We have adopted this excellent suggestion and conducted two robustness analyses by comparing authors in the same authorship position and the same broad discipline. Table R3 below confirms our findings. We have added this analysis to the main text and SI.

Table R3: Coefficients of all variables in Model 5 (our most comprehensive model from the original manuscript) that predicts **whether the author self-promoted the paper**. A separate model is fitted to the first authors in Social Sciences and the last authors in Natural Sciences. Coefficients for 26 Scopus Subject Areas are included in the model but omitted here for clarity.

	Social Sci. (First Auth.)	Natural Sci. (Last Auth.)
Woman	−0.209***	−0.241***
Author previous num. of publications	0.395***	0.291***
Author previous num. of publications (squared)	−0.025***	−0.030***
Affiliation rank	−0.032***	−0.066***
Affiliation location international	0.250***	0.073***
Number of authors	−0.041***	−0.004***
Journal impact factor	0.090***	0.033***
Author log citations	−0.093***	0.037***
Publication year 2014	0.312***	0.354***
Publication year 2015	0.672***	0.693***
Publication year 2016	0.937***	0.965***
Publication year 2017	1.199***	1.344***
Publication year 2018	1.561***	1.706***
Intercept	−3.173***	−4.489***
Observations	205,398	1,751,444

Comment 1.7

Format.

5. You should avoid using abbreviated variable name extensively. For example, a lot of the variable names in Table S1 are abbreviated and readers would have to guess what you meant with each variable (e.g., I know “author_pub_count_cat” is about author publication count, but I don’t know how exactly you measure author publication count; how is affiliation rank measured?). Adding explanation for some of the variables will help if they are not straight-forward continuous.

Response

We thank the Reviewer for pointing out this issue that impacts the readability of our paper. We have revised the paper substantially to address any presentation issues. Accordingly, these abbreviations have been fixed throughout the paper. We added the explanation of all variables to SI Supplementary Text, Section E.

1.2 Response to Reviewer 2

Comment 2.1

Referee report for NCOMMS-24-13075 The Gender Gap in Scholarly Self-Promotion on Social Media.

The paper analyzes the tendency of male and female scholars to promote their research on Twitter, finding that women are significantly less likely to engage in self-promotion than men, even after controlling for a battery of factors. This gender disparity persists across different scientific disciplines and is pronounced among high-achieving women from prestigious institutions. The paper is well-written, and the empirical results are quite comprehensive. Here are a few comments and suggestions:

1. The paper appears to equate academic productivity with career stage by using the number of publications and citations as measures. Although these are correlated, I would recommend using a more standard proxy, such as the number of years since the first publication.

Response

We greatly appreciate the positive feedback from Reviewer 2.

We agree that academic productivity (measured as the number of publications) is not an appropriate proxy for career stage. To describe our measure more accurately, we now exclusively use “academic productivity” in describing our original findings. We argue that this measure of productivity is a critical indicator of experience in terms of published work.

However, career stage is also an interesting variable, which can incorporate complicated gendered aspects due to, e.g., women taking longer breaks for childrearing and/or eldercare. Quantifying career stage as the number of years since the author’s first publication, as suggested by the Reviewer, yields consistent results. Fig. R1 below shows that the gender gap in self-promotion probability increases with author’s academic age but plateaus in the mid-to-late career stage. We have added this additional analysis in the main paper and SI.

Comment 2.2

2. In similar vein, it would be beneficial to include more controls related to Twitter usage, beyond just the number of followers; for example, the year the account was created, average activity levels (tweets, retweets, likes), and the nature of the follower/following circle (whether it includes more academics, which might indicate whether the account is used more for private or scholarly purposes).

Additionally, was the follower count measured at the time of self-promotion, or was the most current number used? If the latter, this introduces an endogeneity issue.

Response

We agree that it is attractive to incorporate these usage characteristics. Unfortunately, the Twitter API is no longer freely available (or even at a reasonable cost) to collect these measures. The follower count is indeed measured at the time of our data collection due to an inherent limitation of the Twitter API, which we note as a limitation in the Discussion.

We want to highlight that we do not take Twitter usage variables into account in our main analysis because variables such as follower count may not be simply exogenous – they could be caused by self-promotion. Thus, we are interested in examining gender gap among scientists

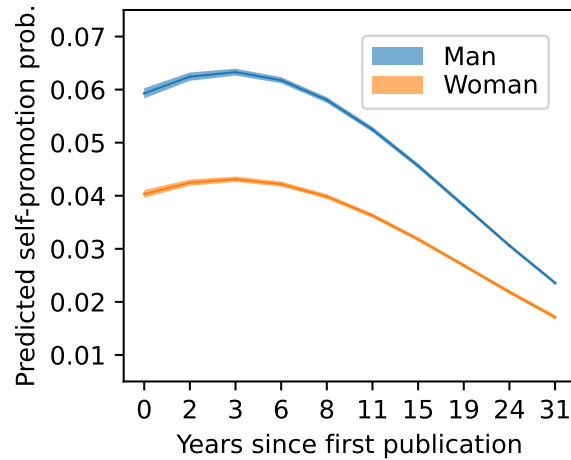


Figure R1: The likelihood of self-promotion as a function of author career stage, measured as the number of years since first publication. The gender gap in self-promotion increases with author's career stage but peaks in the mid-to-late career stage. The prediction is based on our most comprehensive model (Model 5 in SI Table S1) that also adds an interaction term between gender and the career stage variable.

doing similar research (for which we add many controls). It is possible that the gender gap in self-promotion may be *partly* driven by Twitter usage differences (as we show in Fig. 2 in the main paper). Future research could try to further distangle the complex relationships between Twitter usage, self-promotion, and return on self-promotion.

Comment 2.3

3. It would be intriguing to discover whether male authors are also more likely to self-promote older research, rather than just new publications. This strategy might be employed particularly when the research topic aligns with current societal interests.

Response

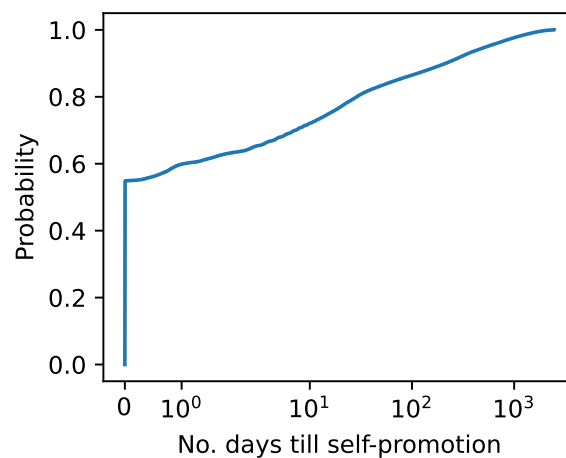


Figure R2: The cumulative distribution of self-promotion timing (in days) among all 480,622 self-promotion observations in our data. About 60% self-promotion cases happen in less than a day after paper publication.

We examined the timing of self-promotion relative to paper publication, with the results shown in Fig. R2. The majority of self-promotion happens within 1 day of publication. Given that self-promotion is already a rare case in our data, with only 4.2% paper-author dyads involving self-promotion (see Comment 1.4), examining “late” self-promotion might rely on data that’s pushing the sample a bit too far. We agree, however, that the hypothesis is intriguing and could be a promising direction for future work, which may have suitable measures of current societal interests that we lack.

Comment 2.4

4. Is it feasible to control for the timing of self-promotion relative to the initial popularity of the publication on Twitter (or mentions in other news outlet from Altmetric)? For instance, controlling for the number of mentions before the self-promotion occurred, and identifying which outlets (news agencies, institutions, another co-author, or academics) were responsible for these mentions.

Response

As shown in the previous response, most self-promotion happens within a day after publication (Fig. R2), and these self-promotional tweets tend to be the initial mentions of a paper. Thus it would be non-trivial to define a time window to measure initial popularity before self-promotion happens. If the time window is too short (e.g., less than a day), we lack variation in this variable to model it properly. If the time window is a bit longer, most self-promotion would already have happened. However, we do not rule out that initial popularity is predictive of self-promotion, but unfortunately, we do not have a large enough sample to investigate this issue.

Comment 2.5

5. Exploring field variations more extensively than just the four broad disciplines would be insightful. For example, the gender ratio disparity between fields within the social sciences, such as economics versus psychology (where economics shows greater female underrepresentation, see Chan and Torgler, 2020), could provide deeper insights.

Response

Following this intuition, we calculated the gender gap in each of the 26 Scopus Subject Areas. Table R4 shows the results from our logit model. Women self-promote less often than men in all subfields except in “Earth and Planetary Sciences” where the coefficient is not significant.

The magnitude of coefficients suggests that the size of the gender gap might be related to a field’s gender representation. For example, the size of the gender gap is indeed slightly different in Psychology and Economics. We have added this finer-grained analysis to the paper and SI.

Comment 2.6

6. While I appreciate the method of measuring the ‘return on self-promotion’ through the total number of tweet mentions, I am skeptical of its effectiveness as it might be confounded by other forms of promotion (e.g., by colleagues, institutions, or news outlets) that are not direct results of the authors’ self-promotion efforts. A more precise measure would examine if tweets that are self-promotional garner more retweets, likes, or shares, indicating higher engagement (see e.g., Chan, Boduazzman, Torgler, 2020).

Response

Our measure compares the total number of tweet mentions in two conditions: (1) with self-promotion vs. (2) without self-promotion. Promotion by others (such as academic institutions

Table R4: The “woman” coefficient in a Model 5 that predicts **whether the author self-promoted the paper**. A separate model is fitted for each of the 26 Scopus Subject Areas. Women self-promote less often than men in all subfields except in “Earth and Planetary Sciences”.

	Subfield	Women’s coefficient	Std Dev	P value
1	Social Sciences	-0.19	0.01	0.00
2	Materials Science	-0.44	0.03	0.00
3	Engineering	-0.34	0.03	0.00
4	Chemistry	-0.46	0.02	0.00
5	Biochemistry, Genetics and Molecular Biology	-0.59	0.01	0.00
6	Medicine	-0.34	0.01	0.00
7	Nursing	-0.22	0.02	0.00
8	Agricultural and Biological Sciences	-0.34	0.01	0.00
9	Pharmacology, Toxicology and Pharmaceutics	-0.50	0.03	0.00
10	Neuroscience	-0.44	0.02	0.00
11	Business, Management and Accounting	-0.22	0.03	0.00
12	Economics, Econometrics and Finance	-0.20	0.03	0.00
13	Chemical Engineering	-0.44	0.03	0.00
14	Physics and Astronomy	-0.39	0.03	0.00
15	Computer Science	-0.27	0.03	0.00
16	Decision Sciences	-0.31	0.06	0.00
17	Health Professions	-0.53	0.03	0.00
18	Psychology	-0.28	0.02	0.00
19	Immunology and Microbiology	-0.53	0.02	0.00
20	Dentistry	-0.21	0.11	0.07
21	Earth and Planetary Sciences	-0.02	0.02	0.30
22	Environmental Science	-0.20	0.01	0.00
23	Mathematics	-0.44	0.04	0.00
24	Arts and Humanities	-0.14	0.04	0.00
25	Energy	-0.14	0.04	0.00
26	Veterinary	-0.21	0.06	0.00

or journalists on Twitter) are taken into consideration in both conditions. This way, we are controlling for gender differences that may already occur without self-promotion (e.g., women may receive more attention than men without self-promoting their papers or the other way around). We have made this critical point of our comparison clearer in the main paper.

Comment 2.7

7. Furthermore, if there is a gender-differential return on self-promotion, this creates a demand-induced supply scenario (where females engaging in less self-promotion due to lower returns). It would be valuable to investigate more deeply whether this discrepancy persists after controlling for these lower returns.

Response

We couldn’t agree more that the demand-induced supply is a plausible explanation and, more generally, it would be great to establish causal effects. However, such an analysis would require a different research design that is outside the scope of this study. Controlling for returns poses its own problems since the returns are potentially endogenous. We note in the discussion that disentangling the complex causal relationship between self-promotion and return on self-promotion is a fruitful avenue for future research:

“Finally, some control variables in our model are not precisely measured due to the inherent limi-

tation of the Twitter API. For example, the follower count is measured at our data collection time, not at the paper publication date. Similarly, we do not take Twitter usage variables into account in our main analysis because variables such as follower count may not be simply exogenous – they could be caused by self-promotion. Relatedly, while we show that self-promotion leads to more return in Twitter mentions, it is also possible that the gender gap in return could influence the gender gap in self-promotion rate. Future research could try to distangle the complex relationships between Twitter usage, self-promotion, and return on self-promotion.”

Comment 2.8

8. A deeper investigation into the qualitative aspects of how self-promotion is conducted would also be beneficial. Did the authors simply share a link, or did they enhance their tweets with additional text, context, or hashtags? The quality of these promotions may significantly influence their effectiveness and reach.

Response

This is a great idea. Per your suggestions, we conducted an initial analysis of the content of self-promotional tweets. To compare the textual content of self-promotion posted by men and women, we analyzed the words and sentiment of self-promotional tweets.

First, we used a software called “Vader” (Hutto and Gilbert, 2014) to predict the sentiment of each tweet. This tool is specifically developed and attuned to detect sentiment expressed in social media posts and is widely used in past studies (Davidson et al., 2017; Cheng et al., 2017). Fig. R3 shows that scholars of both genders tend to share non-negative sentiment in self-promotion, which is not unexpected.

Second, to examine how men and women use different words to convey positive sentiment when sharing their research, we analyzed each of the 25 positive words used in a scientific context (collected in (Lerchenmueller et al., 2019)) and compared their usage by men and women in self-promotional tweets.

Fig. R4 shows that men use promotional words (Millar et al., 2022) such as “novel,” “excellent,” “robust,” “remarkable,” and “unprecedented” more often than women, while women use supportive words such as “amazing,” “creative,” “supportive,” and “inspiring” more often than men when promoting their research. Other positive words often used by both men and women in self-promotion include “unique,” “bright,” “prominent,” and “assuring.” The gender differences in the use of positive words suggest that not only do men and women self-promote at different rates, but also that they frame differently the associated language and sentiment. We have added these preliminary analyses to SI, Section H.

Comment 2.9

9. Concerning Twitter name-matching, are female scientists more likely to use pseudonyms (possibly due to online harassment, as suggested)? This could underestimate the actual rate of self-promotion among females and, paradoxically, using a pseudonym could undermine the purpose of self-promotion. This aspect warrants further discussion.

References:

- Chan, H. F., & Torgler, B. (2020). Gender differences in performance of top cited scientists by field and country. *Scientometrics*, 125(3), 2421-2447.
- Chan, H. F., Bodiuzzman, S. M., & Torgler, B. (2020). The power of social cues in the battle for attention: Evidence from an online platform for scholarly commentary. *Journal of Informetrics*, 14(4), 101077.

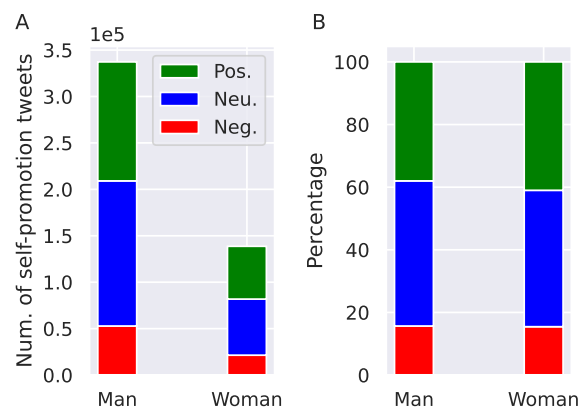


Figure R3: Both women and men are mostly using non-negative sentiment when self-promoting their research on Twitter. *A*, the number of positive, neutral, and negative tweets that involve self-promotion by men and women. *B*, the percentage of three types of tweets by gender.

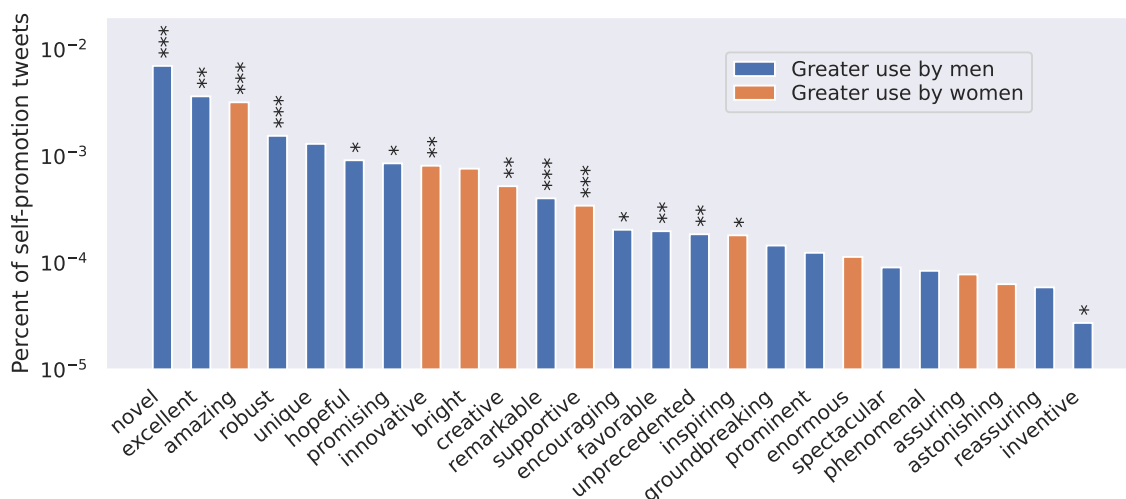


Figure R4: Gender differences in the usage of 25 positive words (Lerchenmueller et al., 2019) in self-promotion tweets. For each word, the variable for each self-promotion observation is set to one if the self-promotion tweet contains that word and to zero if it does not. The y-axis shows the average fraction of self-promotion tweets that have used each positive word. This figure shows that men use promotional words such as “novel,” “excellent,” “robust,” “remarkable,” and “unprecedented” more often than women, whereas women use supportive words such as “amazing,” “supportive,” and “inspiring” more often than men when promoting their research. Each statistical test is based on a Mann–Whitney U test of the distribution of word frequency by both genders. Significance levels: *** $p < 0.001$, ** $p < 0.01$, and * $p < 0.05$.

Response

Thank you for pointing out this plausible scenario. It would be a very challenging task to reliably identify at the scale of our study authors who use pseudonyms on social media. When more powerful methods or more reliable (potentially self-reported) data become available, we could examine how this behavior contributes to the gender gap in self-promotion rates. However, as the Reviewer notices, women using pseudonyms would not fully benefit from the purpose of self-promotion. We have added this limitation to the discussion.

1.3 Response to Reviewer 3

Comment 3.1

Thank you to the authors for their important work. The results are clear and compelling, and the authors' methods are well suited to address their research questions.

I am enthusiastic about this paper, though I believe it can be developed in several respects. I do not take issue with the data collection and methods (though see my comments on gender categorization), but more so with fundamental assumptions of what the paper can and cannot tell us; the paper should be upfront with this and engage more deeply with these complexities.

I see the paper as a first step in understanding the extent of self-promotional differences on social media and how we can alleviate them.

The paper's limitations regarding intersectionality are particularly emblematic of other steps that must be taken in future investigations.

Response

We greatly appreciate the Reviewer's enthusiasm about our paper. We are thankful for this summarization and address the Reviewer's insightful comments below, including the shortcoming of our analysis regarding questions of intersectionality.

Comment 3.2

- First, It is important to mention the wider context in which Twitter/X sits within, and whether its values are misaligned with societal expectations for women's behavior. We are aware of the many ways that the platform aggrandizes sense of self-importance, combative behavior, machiavellianism, and low cognitive reflection - several papers in this journal have led our understanding in these respects. It is not a coincidence that the cultural construction of patriarchal masculinity has considerable overlap with the social/behavioral constructs that proliferate within the platform. In other words, Twitter is not a gender neutral "tabula rasa" social media platform - the culture that the app nurtures is gendered, meaning that it may be an "icy climate" for some individuals more than others. Please account for this in your introduction and discussion.

Response

This is a critical point that needed strengthening in our paper. Per your suggestion, we have added the literature on social media masculinity and cultural norms in the introduction to motivate our hypothesis. We highlight that Twitter is a testbed for our study and has some important particularities. These arguments are valuable as they also reveal some of the reasons one cannot assume that the gender gap in self-promotion is already well established on Twitter or social media more broadly (c.f. Comment 1.2 and Comment 1.3). We added to the introduction:

"However, some social media platforms such as Twitter promote self-importance, combative behavior, and masculinity (Maaranen and Tienari, 2020). This may create a potential misalignment between cultural norms on Twitter and societal expectations of women's behavior, which can further nurture a more unwelcoming culture for women, impacting their willingness to self-promote."

Comment 3.3

- While you are able to show that differences in self promotion cannot be explained by there simply being fewer women on Twitter, it is useful to consider what types of women are on twitter. This makes your results more compelling, as women who are on the platform have some interest in online visibility and do not find Twitter to be culturally impoverished enough of a space to withdraw their participation from it entirely. This means that among women who have met the threshold of being interested in a platform that is inherently self-promotional, the gender gap still exists.

Response

Per your insightful comment, we have added this interpretation to the discussion:

“Crucially, differential adoption and usage of Twitter do not explain the full gap. While our results show that women are slightly underrepresented on academic Twitter relative to men, the gender gap in self-promotion appears even among those active on Twitter. This is surprising as women who are active on Twitter already have some interest in online visibility. Critically, then, our findings suggest that even for women who are interested in an inherently self-promotional platform, the gender gap still exists.”

Comment 3.4

- Please include some type of quantification of the number of papers published in a given year overall compared to the number of papers that are mentioned on Altmetric in that same period. It would also be helpful, if at all possible, to provide numbers around overall gender differences in number of academics on twitter vs. those who are not - considering that you show “men are indeed more likely than comparable women to be active on Twitter.” Providing some visualizations on this will drive home the context in which your analyses are situated, and will perhaps also provide a sense of scale.

Response

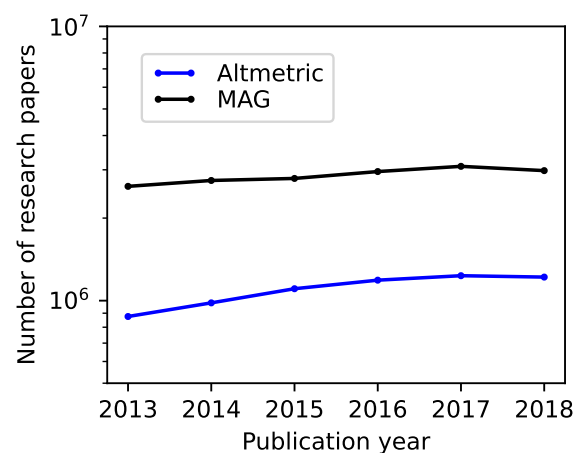


Figure R5: Altmetric.com tracks about 27% of all *research papers* indexed in the Microsoft Academic Graph (MAG) database, which is our baseline for published papers.

Fig. R5 shows the number of research papers indexed in the comprehensive Microsoft Academic Graph (MAG) bibliometric database and the Altmetric database. It shows that Altmetric.com finds online mentions for about 27% of all *research papers* covered in MAG. We have added this

information in the Materials and Methods section to clarify the scope of our study.

In our data, the percentage of authors active on Twitter is 4.6% for women vs. 5.9% for men. However, this might be an underestimation because we were unable to identify all scholars on Twitter when their usernames could not be connected to their author names. We have added these statistics in the paper to better describe our sample and contextualize the findings.

Comment 3.5

- I'm aware that you cite your gender verification method as a limitation. This said, still please provide significantly more detail on how your model is accounting for racial and ethnic differences in gendered names. What confidence should we have that in comparing "the algorithm's inferences to an auxiliary dataset containing the self-reported gender of 432,888 physical scientists," this list is race representative? Presumably, this list of scientists would mirror known representational problems in science, of which the physical sciences is notorious. How many of the people on this list are women? How many have names that are not easily categorized using Western-centric naming conventions? This list should be available.

Response

We appreciate this comment and agree with the Reviewer that not considering race/ethnicity and intersectionality is a key limitation of our paper. We have added this to the discussion, inviting further culturally and racially aware research on the topic of self-promotion. One important impediment to conducting truly informative intersectional studies at scale is the unreliable accuracy of race and ethnicity labeling tools. In particular, name origin is not a true reflection of ethnicity (Peng et al., 2024; Lockhart et al., 2023), neither is skin color or other visual clues from images.

The auxiliary dataset of physical scientists contains self-reported country of affiliation but not race or ethnicity. The top three countries in terms of number of authors are China (71869), India (47706), and the US (43871). So authors affiliated with non-Western institutions are well represented in this dataset. Yet, women (self-reported) only account for 18.9% of all authors, which, as the Reviewer notes, is typical in the Physical Sciences.

The gender classifier works better for Western than for East Asian names (Lockhart et al., 2023), particularly when the names are written in Latin characters (which are often predicted to be unisex). Thus, our reported accuracy of gender prediction on the full dataset is more representative of Western names. We added both limitations to the discussion:

"Second, we use name-inferred gender as a proxy of the author's true gender identity. Our two validations show that, overall, there is a high degree of agreement between the predicted and self-reported or manually verified genders. However, the dataset of physicists used in our validation is not gender-balanced, as only 18.9% of the authors self-reported to be women. Thus the accuracy of gender labeling may be lower than reported. Relatedly, our validation result is more applicable to Western names because many East Asian names do not have a distinctively predicted gender label and are thus excluded from our evaluation (Lockhart et al., 2023; Peng et al., 2024)."

The self-reported gender comes from a dataset from the Institute of Physics (IOP). Our collaboration with IOP is governed by a data-use agreement and an IRB that prevents us from sharing these personally identifiable data.

Comment 3.6

- How do you make sense of the growth in self-promotion gender differences? This is why it is vital to provide more context on the operation and culture of the platform you are studying, which has become gradually more entrenched in masculine norms and outwardly masculinist ownership (your data can of course not account for when the ownership change occurred).

Response

We have added an interpretation of the increase in the gender gap in self-promotion by relating it to the changing culture and norms on Twitter. We write in the paper:

“The gender gap appears to have increased over the six years studied here. One possible reason behind the increase might be related to cultural change on Twitter, which has increasingly adopted masculine norms that might deter women from promoting themselves.”

Comment 3.7

- Is it possible that your effect of “authors with gender-neutral names self-promote less often than those with gender-distinct names” may be influenced by racially and ethnically differentiated norms around self-promotion? Are those with gender neutral names randomly distributed across race and ethnicity? How is this being disentangled?

Response

This is a potentially critical explanation that we cannot fully verify given our lack of reliably establishing race and ethnicity for our 3.5M authors. Since authors from certain countries such as China are more likely to have gender-neutral names (Lockhart et al., 2023; Crabtree et al., 2023; Peng et al., 2024), the mentioned additional finding is likely to be driven by ethnically different norms around self-promotion. Future research, potentially relying on self-reported race and gender information or more advanced computational tools, should carefully examine questions related to race and intersectionality.

We have added this promising direction to the discussion:

“Indeed, we find that including authors with gender-neutral names in the analysis shows that these scholars are the least likely to self-promote. Since authors from certain countries such as China are more likely to have gender-neutral names (Crabtree et al., 2023; Lockhart et al., 2023), the lower self-promotion rate of authors with gender-neutral names may be driven by racially and ethnically differentiated cultural norms around self-marketing on social media. For example, regardless of gender, self-promotion may be considered more acceptable in Western than East Asian cultures. Addressing this issue around race and ethnicity would be difficult due to challenges in the algorithmic categorization of these categories (Lockhart et al., 2023; Peng et al., 2024). We thus view our focus on gender as a contribution to understanding one form of disparities in scholarly recognition and visibility. Further work should investigate intersectionality in self-promotion and examine the specific challenges that underrepresented groups face in self-promotional contexts. Another related limitation of our analysis is that authors of non-binary gender are not identified, which we hope future work can rectify.”

Comment 3.8

- You mention “men’s higher enthusiasm and greater returns for self-promotion, but you have not measured enthusiasm. It seems entirely likely that women may be enthusiastic but that several barriers keep this enthusiasm from translating into actual self-promotion on Twitter.

Response

Thank you for pointing out this issue. We have now removed this claim.

Comment 3.9

- There is room to develop your implications and practice section. You assume that it is women who should catch up to men’s self promotion through institutions providing “provide training, dedicated time, and support.” Is this not another non-promotional use of women’s time? Should we endeavor for work to be featured on Twitter, or are there other, perhaps more creative ways to democratize how papers are shared and made visible without perpetuating existing hierarchies within the academy? How might hiring and tenure committees be made aware of the headwinds women face in self-promotion, and how men’s opportunities and collaborations may indeed be shaped by self-promotion culture? I’d like to see much more substantive and creative thinking in this vein rather than the blanket assumption that all scholars should meet a culture that is, by your own findings, set and maintained by men.

Response

This is a great point and, frankly, an unfortunate oversight on our parts. We have revised and enriched the discussion of implications, making sure not to assume that the gap needs to be closed by the actions of women. Here is the revised text:

“This should be considered when using such metrics in research evaluation, especially in high-stakes decision-making such as hiring, promotion, and tenure. First, simply informing individuals about the gender gap may affect behavior and judgment (Régner et al., 2019). Institutions should consider informing their employees, including staff, faculty, and any selection committees, of the gender gap in self-promotion and possible downstream effects on academic outcomes. Such information may also affect, for example, which readings instructors choose for their courses or recommend to their students, which speakers get invited, and who is considered for an award.

Scholarly practices aimed at closing the gender gap in visibility should rely on interventions that aim to “fix the institutions” not “fix the women” by placing additional burdens on them (Recalde and Vesterlund, 2023). Our work highlights that online platforms are likely to perpetuate existing hierarchies within the academy through self-promotion. Democratizing how papers are shared and made visible demands a collective effort. One possibility is that institutions *proactively* support the promotion of research outputs through equity-minded press offices. More effectively, researchers could engage in peer promotion, as this does not trigger backlash (Amanatullah and Morris, 2010; John, 2021). Similarly, participation in mentorship programs that offer promotion and advocacy by senior sponsors may be another solution (Ibarra, 2022).”

Comment 3.10

- There must be an acknowledgement in your limitations about race. The problem of self-promotion is certainly not just gendered, but is likely to also have racial components whereby people of color are more likely to underestimate the quality of their work and receive more backlash for self-promotion. White men are likely self-promoting more than some men of color. This paper is not able to shed light on this, and the reasons why this would be difficult and problematic to estimate (algorithmic categorization of race), should be acknowledged. But there is no doubt that you are studying an intersectional phenomenon that cannot be analyzed in its intersectional entirety.

Remarks on code availability:

Code appears reproducible.

Response

Per your suggestions, we have added a detailed discussion about race, intersectionality. Accordingly, we added the following limitation in our discussion:

“Fourth, our study does not analyze race/ethnicity and their intersectionality with gender in self-promotion. However, the observed gender gap in self-promotion is likely to vary between different races and ethnicities. The literature shows that intersectional categories develop bias in self-assessment regardless of actual performance (Baugh and Graen, 1997), have a heightened sensitivity to unprofessional feedback (Silbiger and Stubler, 2019), and receive worse treatment and fewer rewards (Cech, 2022).”

We also discuss how our study on the gender gap in self-promotion contributes to understanding one form of disparities in scholarly recognition and visibility (see quoted text in Comment 3.7).

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1 Point-By-Point Discussion

1.1 Response to Reviewer 1

Comment 1.1

Thank you for your effort to address my questions and concerns raised in the earlier round of review. Again, I appreciate your empirical effort. I don't doubt the core result of your paper with regard to the existence of a gender gap in the tendency of self-promotion on Twitter (currently X). However, I don't believe that the motivational questions I raised in the previous round of review have been sufficiently addressed. Ultimately, the main challenge is still the "so what" question. As I noted in my previous referee report, the gender gap exists on many fronts in science and among scientists. Can the findings based on this paper inform policies for interventional measures that can reverse the gender gap with regard to important outcomes in science? Scientists' time and energy is constrained. Can we use the knowledge from this paper to persuade women scientists to increase their effort of self-promotion on Twitter or other social media platforms? The answer is ambiguous, particularly given your finding that return to self-promotional activities is not very much in favor of women.

The fraction of scientists who went on to Twitter to post messages is small, and the fraction among them who self-promote is even smaller. To what extent knowing any gender gap in this activity can improve overall gender inequity in science? This is at the core of my request for you to motivate your research paper more carefully. Unfortunately, I am not convinced that this issue has been resolved in this revision.

We agree that it is very important to motivate our paper clearly and appreciate your push to do this better. We interpret your comments (and our motivation challenge) as having three parts, which we address below.

1. Distinction between self-promotion on social media and important outcomes in science

Professional use of social media in academia has been an active topic of discussion for at least a decade (Van Noorden, 2014; Editorial, 2018; Yammine, 2020; Docter, 2024; Thornton, 2021; Lee, 2019). Many scientists devote considerable effort to self-promotion, networking, and learning on social media platforms (Harseim and Goodey, 2017; Van Noorden, 2014; Lee, 2019; Van Eperen and Marincola, 2011), when in theory they could be doing other things. The outcomes of self-promotion, such as engagement and diffusion, may be crucial for careers (Qiu et al., 2024) and the public's knowledge of latest findings (Van Eperen and Marincola, 2011), although more evidence is needed.

Consequently, in our view, what scientists publicize on social media is deserving of careful empirical investigation, and may itself represent "important outcomes in science" rather than mattering only if linked to *traditional* important scientific outcomes such as jobs and citations (although evidence for these links is getting stronger every year (Stephen and Stahlschmidt, 2024; Peres et al., 2022; Chan et al., 2023)).

2. Is the sample of self-promoters substantively significant?

We have two points to make here. First, we do not only analyze the sample of self-promoters. We are able to quantify the gender gap in self-promotion among *all 3.5M authors* in our data (Fig. 2A in the main text), and *additionally* decompose it into the gender gap in Twitter use (Fig. 2B in the main text) and in self-promotion conditional on Twitter use (Fig. 2C in the main text).

Second, while it is true that self-promoters are a fraction of all authors, we think it is a substantively significant subset. In our data, the number of scientists active on Twitter is $N = 618,742$ (Fig. 2C and Fig. 4 in the main text). This is very likely an underestimation due to inherent

challenges in matching authors to their Twitter accounts based on author names and their screen names (Costas et al., 2020). As one piece of evidence, a 2017 Nature survey with more than 3,000 respondents found that over 95% participants indicated being active on Twitter and other social media platforms (Harseim and Goodey, 2017).

So, overall, we believe that 618K scientists is not a fringe sample. After documenting the overall gender gap in self-promotion among all authors regardless of Twitter use, we go a step beyond and show that this gap is not entirely due to differential Twitter use, but also exists among this very large sample of authors active on the platform (Fig. 2C in the main text).

3. “To what extent knowing any gender gap in this activity can improve the overall gender inequity in science?”

This is a fair question, which we think is also a challenge for the broader literature on gender inequities in science. Previously, we argued that documenting the gender gap in self-promotion is important because the literature finds that there is a positive link between Twitter promotion and more consequential outcomes such as citations. However, we did not discuss concretely how knowledge of gaps might lead to interventions and reduction in inequities. Here, we want to fill that gap by highlighting one concrete mechanism: informing people about gender gaps can affect their subsequent opinions and behavior (Klysing, 2020; McCall et al., 2017; Weisgram and Bigler, 2007; Régner et al., 2019). For example, informing students about the existing gender gaps in teaching evaluations leads to reduced gender gaps in evaluations (Peterson et al., 2019); teenage girls who learned about gender disparities in science show increases in their belief in the value of science (Weisgram and Bigler, 2007).

Studies like these show that revealing gender gaps can be consequential. In our case, they may affect the amount of self-promotion scientists do. This literature also shows that the effects may not be as straightforward as the group in the “lower” part of the gap acting to close it. In the context of our study, the expected (or desired) effects are not necessarily to persuade women to self-promote more; men might be induced to self-promote less, or promote female colleagues more, etc. Additionally, knowledge of this gap may also affect how hiring and promotion committees interpret gender gaps in outcomes like citations. Any such interventions and changes to evaluation must begin with establishing the gap first, which we contribute to in this paper.

We thus included the following language in the Introduction:

“Studying gender gaps in self-promotion is thus critical for understanding women’s potential underrepresentation and lack of inclusion in science-related conversations. Raising awareness of such gender gaps is a prerequisite for improving research policy through properly accounting for biases that appear in the public’s opinion about who is driving scientific progress and innovation (Peng et al., 2024), which can affect young people’s career choices (Weisgram and Bigler, 2007) and shape career-critical promotion decisions in academia (Régner et al., 2019). More broadly, informing people about gender gaps in self-promotion can affect their subsequent opinions and behavior (Klysing, 2020; McCall et al., 2017; Weisgram and Bigler, 2007; Régner et al., 2019) and contribute to targeted interventions that promote gender equity in science (Peterson et al., 2019; Cundiff et al., 2018; Moss-Racusin et al., 2016).”

“Through revealing a systematic gender gap unknown to scientists and academic decision-makers, our study can stimulate further research on gender inequity in science, ultimately contributing to gender balance in many important scientific outcomes. We discuss practical implications of our research on designing effective policies and interventions for closing the gender gap in visibility and academic careers.”

Comment 1.2

One other issue: the title and abstract seem to suggest that the results reported in the paper are about gender gap in self-promotion in Twitter. Yet, if I understand it correctly, most of the models of likelihood of self-promotion are estimated on the risk pool of scientists who have records on Twitter (Twitter adopters). This is not reflective of the real gender gap of social media self-promotion among the general population of scientists – to estimate that gap, you would need a different risk pool. This point has not been clearly stated in the paper and is thus somewhat misleading. (Remarks on code availability): I have not installed the codes.

Our models of self-promotion are based on all authors in our data (Fig. 2A, Fig. 2B, Fig. 3 in the main text). We only limit the analysis of the gender gap among Twitter-active users (Fig. 2C) and the analysis of return on self-promotion to scientists who have records on Twitter (Fig. 4), because this allows us to further control for their follower count, which can influence the total number of tweet mentions of a paper. We have clarified the sample size in figure captions.

Comment 1.3

While propensity score matching helps resolve confounding issue (that the types of scientists who Twitted are different from the types of scientists who didn't), it is not a not reliable solution as you are relying on the assumption that observable variables can fully account for the confounding factors. Yet, this is a strong assumption to make.

We used propensity score matching to compare self-promotion rates among women and men doing comparable research and are of similar academic impact or reputation. You are absolutely right that this technique will not account for unobservable confounding factors beyond these characteristics. This analysis only serves as a robustness check and is included in our supplementary material. We hope that our observational evidence can motivate future research to experimentally test the gender gap in self-promotion, checking for additional factors that we could not observe at the scale of our study ($N = 3.5$ million scientists).

1.2 Response to Reviewer 2

Comment 2.1

The authors have provided detailed and thoughtful responses to my previous comments. They have provided extensive additional new analyses (particularly on career stage and field variations) which improve the manuscript. I appreciate their willingness to engage with most of the points raised and their transparency about the limitations in some cases. I believe the manuscript is much stronger as a result of these revisions, and I am satisfied with the overall responsiveness of the authors and recommend the revised version for publication.

Below is the assessment by my co-reviewer: This paper presented valuable insights regarding the gender gap in scholarly self-promotion online, and the authors thoroughly addressed Reviewer 2's feedback. Where possible, they conducted additional analyses as recommended, which were sufficiently explained within the main paper and/or supplementary materials. Where it was not feasible to examine the questions raised by the reviewer, the authors provided valid justification as to why this was the case and articulated these additional limitations/extensions clearly in the paper's discussion.

We are grateful for the positive recommendation by Reviewer 2 and the Co-Reviewer.

1.3 Response to Reviewer 3

Comment 3.1

Thank you to the authors for your hard work on this revision. For the sake of consistency I will stay within the remit of my original review. In general, I am satisfied with the authors' changes to the manuscript and I believe this paper is acceptable for publication. My thoughts on the importance of this matter and appreciation to the authors for bringing it to light remain.

We greatly appreciate your positive recommendation of our paper for publication.

Comment 3.2

I would like to mention, however, that I feel most of my comments have been addressed via lip-service rather than a deeper grappling with the meaning of women's self-promotion in an academic/social environment that privileges men and traditional masculine norms. You have addressed my comments by adding in language that is similar to my suggestions, but I was hoping for these threads to be reflected more in the overall tone and ethos. I have been discouraged by seeing, even in a paper about gender, an almost reflexive tendency to point towards women's behavior rather than problems with the culture women are situated within.

I would aim to actively work against a tone in your introduction that seems to imply that women should be self-promoting more, rather than suggesting that men should potentially self-promote less and without exaggeration of their achievements (doesn't it also make sense that women self promote less if they have less to gain from it, as this paper's results suggest?)

For example, thoughts like the following are offered without context: "A growing literature finds that women spend more time on non-promotable tasks, such as emotional support towards trainees and academic service." Because you don't interpret this, your reader may take away that women shouldn't be doing those non-promotable tasks and should be self-promoting more instead. Why not work to reframe some of these sentences in ways that show that men often do not do their fair share of non-promotable work, in order to create a sense of balance in this introduction? In fact, such non-promotable work is key to students' educational experience and the running of a department. This is the type of ethos change, rather than a simply language change, in which I would like to see a more comprehensive engagement.

On this same note I wonder if it would be useful to mention that education opportunities on the gender gap in self-promotion would be specifically useful to online men in academia, who are the biggest stakeholders in upholding and potentially changing the current culture.

Whether you need to address this feedback should be a matter of the editors' discretion.

(Remarks on code availability): Code appears reproducible.

Thank you for clarifying your original concern about the framing of our paper. Following your suggestion, we have significantly adjusted the tone in the introduction to emphasize the problematic masculine workplace culture that disproportionately advantages men over women.

Accordingly, we have revised the writing of our main text to avoid suggesting or implying that

women need to keep up with men by self-promoting more in order to be successful. We point out that men's high self-promotion may encourage salesmanship and exaggeration that can undermine the quality of science (Landis et al., 2012; Millar et al., 2023).

We also considerably improved the policy implication of our findings in the discussion. We highlighted that the findings from our paper should not be used to encourage women's more participation in self-promotional activities, but rather be used as a guideline for policy interventions and institutional initiatives aimed at closing the gender gap in visibility and other important outcomes in science.

We have added the following text in the discussion:

“Despite these limitations, our study offers valuable insights into scholars' self-promotion on social media, enriching our understanding of the broader gender inequity in scientists' online visibility and recognition. First, our work informs the way we interpret online visibility metrics and traditional performance indicators shown to correlate with them such as citations (Stephen and Stahlschmidt, 2024; Chan et al., 2023; Peres et al., 2022; Bardus et al., 2020). Lower visibility metrics for women are a systemic issue with complex underpinnings and are explained at least in part by men's higher self-promotion rates and the larger returns they receive from it. This should be considered when using such metrics in research evaluation. Criteria for hiring, promotion, and tenure should thus be adjusted to ensure that more favorable conditions for men's self-promotion do not disproportionately disadvantage women.

Second, simply informing individuals about the gender gap may affect collective behavior and judgment (Klysing, 2020; McCall et al., 2017; Weisgram and Bigler, 2007; Régner et al., 2019). In our case, revealing the barriers to women's self-promotion can raise awareness of specific challenges that can trickle down to affect their career progression. This awareness can gradually lead to a cultural shift within the broader scientific community, encouraging more equitable research evaluation. Practically, institutions should consider informing and educating their employees, including staff, faculty, and any selection committees, about the gender gap in self-promotion and its possible downstream effects on other important academic outcomes. Such training programs may also affect, for example, which readings instructors choose for their courses or recommend to their students, which speakers get invited, and who is considered for an award.

Third, scholarly practices and policies aimed at closing the gender gap in visibility should rely on interventions that aim to “fix the institutions” not “fix the women” by placing additional burdens on them (Recalde and Vesterlund, 2023), especially given that women's self-promotion is not as effective as men's. Our work highlights that online platforms are likely to perpetuate existing hierarchies within the academy through self-promotion. Democratizing how papers are shared and made visible demands a collective effort. One possibility is that institutions *proactively* support the promotion of research outputs through equity-minded press offices. Relatedly, professional organizations can launch initiatives to increase the visibility of female scientists and their work by highlighting their achievements in newsletters, websites, and social media, as well as nominating them for awards and speaking opportunities. Additionally, researchers of any gender could engage in peer promotion, as this does not trigger backlash (Amanatullah and Morris, 2010; John, 2021). Similarly, participation in mentorship programs that offer promotion and advocacy by senior sponsors may also help (Ibarra, 2022).

Our study can encourage future research to examine mechanisms causing the gender gap in self-promotion. Such investigations would be critical because algorithms on online platforms may amplify small initial differences, as produced via differential self-promotion, into large disparities in ultimate attention (Sasahara et al., 2021; Ciampaglia et al., 2018) and conventional markers of scientific excellence (Chan et al., 2023; Luc et al., 2021; Peres et al., 2022). Additionally, future work utilizing surveys to gauge perceptions of self-promotion could examine why the gender gap is substantial even in relatively gender-balanced fields and why it is larger when promoting achievements widely considered valuable, such as papers in high-impact-factor journals.”

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