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Original article

Gender differences in time taken for peer review and publishing output in the physical sciences

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Competing interests

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The original data set can be obtained from the author on request.

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Abstract

Background: Despite decades of work to improve gender equality in science (and other science, technology, engineering, and maths fields), gender bias still exists and has been shown to impact the retention of women in academic scientific careers. Publication of peer-reviewed articles remains a key criterion for career progression and a common marker of success in academia. Any barriers to publication faced by women may therefore impact their retention and career progression.

Objectives: To investigate gender differences within one potential barrier to publication, namely the time taken in peer review, by investigating the question: 'Is the peer review process longer for papers with (assumed) women as first authors than those with (assumed) male first authors?'

Methods: Gender differences in peer review time were analysed for 1100 peer-reviewed papers published between 2006 and 2016 and selected from 5 journals covering a range of physical science disciplines and publication styles.

Results: In the physical sciences, male first-authored papers outnumbered female first-authored papers 2:1. However, the analysis showed no statistical difference in the time taken for peer review between the two sets of papers.

Conclusion: The time taken to peer review a paper is not linked to the gender of the paper's first author. However, the large discrepancy in the number of papers with men as first authors compared to that with women as first authors could be a contributing factor to the attrition of women from the academic career ladder (the so-called 'leaky pipeline').

Keywords:

Gender bias in peer review, gender bias in science, gender of first authors

Introduction

Explicit efforts to increase equality of opportunity for women in the fields of science, technology, engineering, and maths (STEM) have been ongoing for decades and yet, data continue to show an imbalance between the achievements of men and women in scientific academia. In particular, the retention of women is an issue. Despite gender parity at levels from an undergraduate degree to early postdoctoral positions, women are still under-represented in permanent faculty positions. A recent (2021) review paper by Llorens et al.[1] collates a wealth of statistics on gender disparities in academia, including data from US National Institutes of Health which reports that '*in the top 10 research institutes in the US the percentage of women with tenure among all professors was at most 26% and in some cases even below 20%*', and a similar story for Europe (only 27% of European Research Council Horizon 2020 funding programme grantees were women). A range of implicit and explicit biases have been shown to hinder the participation of women across a range of academic tasks, from speaking opportunities at conferences[2] to opportunities to review papers.[3]

Despite recent drives to move the definition of what constitutes a successful academic career away from publication-driven metrics, for example, the journal impact factor (DORA, 2012),[4] the number, and perceived quality of one's publications are still important metrics used to determine hiring and promotion.[5,6] For this reason, any gender bias in the publication process may hinder the progression of women. Evidence from an analysis of publications in academic economics suggests that women-authored (in this paper, the terms 'women-authored' or 'men-authored' refer to the first author of the publication) papers spend an average of 6 months longer in peer review than those authored by their men counterparts.[7] The authors attribute this difference to women-authored papers being potentially held to higher standards during the review and editorial process. The period between one's doctorate and a permanent academic position commonly consists of fixed-term contracts of somewhere between 6 and 36 months. Given the relatively short length of these postdoctoral contracts, a 6-month lag in getting a paper to publication could be a significant factor when it comes to perceived productivity at the end of a contract. This 'hidden toll' on women academics may contribute to the attrition of women (compared to that of men) from doctoral level to tenure or faculty posts that has been reported.[1,8] For this reason, this study was conceived to investigate gender differences within one potential barrier to publication, namely the time taken in peer review, by investigating the question: 'Is the peer review process longer for papers with (assumed) women as first authors than those with (assumed) male first authors'?

Methods

Journal and article sample selection

To investigate the above question within scientific academia, the following five journals were selected that covered a range of physical science disciplines and publication styles: *Atmospheric Chemistry and Physics* (*ACP*), *Deep Sea Research* (*DSR*), *Journal of Geophysical Research* (*JGR*), *Nature Geosciences* (*NG*), and *Proceedings of the National Academy of Sciences* (*PNAS*). Currently, *JGR* is organised into seven sections, and we used two of these: *Solid Earth* (*JGR-SE*) and *Biogeosciences* (*JGR-B*). Note that abbreviations used in this article are for consistency and brevity and may not represent the journals' official abbreviations. More details about the journals are provided in Table 1.

These journals were selected not only to cover a variety of physical science disciplines

Table 1. Journals selected for study

Journal	Abbreviation	5-Year journal impact factor[a]
Atmospheric Chemistry and Physics	*ACP*	5.958
Proceedings of the National Academy of Sciences of the United States of America	*PNAS*	10.620
Deep Sea Research	*DSR*	2.872
Journal of Geophysical Research: Solid Earth	*JGR-SE*	4.191
Journal of Geophysical Research: Biogeosciences	*JGR-B*	4.225
Nature Geosciences	*NG*	16.103

[a]As ascertained on 13 October 2020 from the websites of the respective journals, ensuring that all used the 5-year impact factor as assigned by Clarivate Analytics.

(because gender difference is known to vary between specialties[9]) but also to control for other factors that may influence the time a paper spends in peer review, such as:

- *Article length:* two journals, *PNAS* and *NG*, had set article lengths at four to five pages and generally three to six pages, respectively, whereas the other journals did not have strict limits.
- *Method of displaying the first author's name:* in *PNAS*, the name was always given in full (as in John Smith), whereas in *ACP*, the first name was shortened to the initials (as in J. Smith) 100% of the time in 2006 and roughly 55% of the time in 2016.

However, the selection of journals to meet these criteria was not wholly random, and the author's prior knowledge did guide the selection (for example, *ACP* and JGR are two commonly published-in journals in the author's department).

For *ACP*, *DSR*, *JGR-SE*, and *JGR-B*, 2 years – 2006 and 2016 – were selected as the focus of this study, and 1100 individual articles (roughly 200 per journal, split evenly between 2006 and 2016) were manually analysed: the first author's name, time spent in review, and length of the paper were recorded. The papers were accessed from the journal's website and selected in date order, with the oldest first. Papers were excluded only if key data were missing (for example, if one of the key dates was not published). For NG, the earliest papers were published in 2008, and papers from the 'early' block were from 2008 to 2009 rather than from 2006. For *PNAS*, papers published in 2006 do not have the relevant submission/acceptance dates shown online (at the time of writing, on *PNAS* website), so only the 2016 papers were used. *PNAS* publishes a range of articles: for this study, only traditional 'Research Articles' (*PNAS* terminology) were used.

A 'double-blind' peer review – one in which the authors as well as the reviewers are anonymised – should theoretically remove any bias associated with name–gender assumptions, as investigated in this study. Author submission guidelines (as published in 2022, that is, at the time of writing) for each journal were investigated, of which only NG was found to offer a double-blind review process, and that too only since 2015.[10] The process is optional and, evidence suggests, is underutilised (only 12% of authors opting for a double-blind review[11]). A very small number of papers in this study may therefore have undergone a double-blind review, not probably large enough to draw any valid statistical conclusions.

Data extraction, gender attribution, and statistical analysis

The name of the first author was recorded exactly as it appeared in the journal article, for example, either as John Smith or as J. Smith. Whenever only the initial was used for the first name, it was researched by following the author's ORCID ID if available, by searching for the paper title in ResearchGate

or Google Scholar, or by looking up the website of the affiliated institution as given in the paper. If none of these returned the full name of the author, it was recorded as 'unknown'. This was the case for 26 (8%) of the 330 such names.

The use of the term 'gender' and the binary definitions 'male or man' and 'female or woman' are complex, and it is not the place of this research paper to discuss these issues – nor do they impact our investigation, which relies on whether most names are perceived traditionally as 'male' or 'female'. For the purpose of this study, 'gender' is used in the traditional binary definition, although the author recognises the diverse nature of gender and sexuality and one's individual right to self-determine this. Traditional definitions of 'male/men' and 'female/woman' will also be used to identify the gender of the first authors of papers in this study. Further useful guidance on the use of sex and gender terminology within academic publications can be found in the 'Sex and Gender Equity in Research (SAGER) guidelines' for editors/authors.[12] Gender was assigned to names using Gender-API, which contains over 1.8 million validated names, crucially – given the international nature of science – from 177 countries. Gender-API assigns names as 'male' or 'female' with a degree of certainty and also uses the label 'unknown'. Where the degree of certainty was less than 75%, we manually assigned this to the 'neutral' category (names such as 'Andreas' and 'Charlie', for example, fall into this category). This is likely to be a conservative barrier for selecting gender-neutral names but was done to prevent any human bias in reading and selecting names considered to be neutral and to account for variation in reviewer perceptions of genders.

Data handling, analysis, and figure production were performed in Excel with the exception of statistical tests (analysis of variance (ANOVA)), which were performed using SigmaPlot. Further details of statistical tests are provided in the relevant sections later.

Results

Analysis of 1100 papers spread across 5 journals resulted in 674 (61%) first authors assigned to the 'male'; 296 (27%) to 'female'; and 130 (12%) to 'neutral' and 'unknown' combined.

The first finding of interest is that men outnumbered women as first authors almost 2:1 (61% vs 27%). This imbalance was observed for all five journals (Table 2).

Details (mean, standard deviation, range, and total count) of the time spent in review for papers with men or women as first authors for each journal are given in Table 3. These results are detailed further and displayed graphically in Figure 1. We found no statistically significant (Kruskal–Wallis one-way

Table 2. Number of papers with women or men as the first author, by journal

	Gender of the first author[a]			
Journal	Man	Woman	Neutral or unknown	Ratio (men:women)
ACP	186	71	43	2.6:1
PNAS	129	54	17	2.4:1
DSR	103	77	20	1.3:1
JGR-SE	65	19	16	3.4:1
JGR-B	58	29	13	2:1
NG	133	46	21	2.9:1
Total	674	296	130	2.3:1

ACP, *Atmospheric Chemistry and Physics*; *DSR*, *Deep Sea Research*; *JGR-B*, *Journal of Geophysical Research: Biogeosciences*; *JGR-SE*, *Journal of Geophysical Research: Solid Earth*; *NG*, *Nature Geosciences*; *PNAS*, *Proceedings of the National Academy of Sciences of the United States of America*.
[a]See Section Methods for how this was determined.

Table 3. Number of days spent in review, by gender of the first author and by journal

	Number of days in review: mean (SD), minimum–maximum, and n[a]						
Gender	**All journals**	*ACP*	*PNAS*	*DSR*	*JGR-SE*	*JGR-B*	*NG*
Man	180 (93) 7–630 n=674	200 (71) 78–500 n=186	117 (25) 25–329 n=129	243 (117) 58–609 n=103	233 (115) 37–630 n=65	180 (62) 52–347 n=58	139 (67) 7–321 n=133
Woman	189 (108) 1–640 n=296	207 (81) 30–490 n=71	120 (56) 18–264 n=54	242 (141) 1–640 n=77	197 (92) 106–427 n=19	184 (88) 64–482 n=29	151 (87) 34–521 n=46
Neutral or unknown	179 (95) 38–613 n=130	206 (72) 99–407 n=43	103 (48) 38–219 n=17	236 (142) 76–613 n=20	207 (104) 76–401 n=16	148 (51) 78–226 n=13	129 (45) 76–248 n=21
P value for ranked ANOVA[b]	0.799	0.808	0.530	0.775	0.366	0.157	0.691

ACP, *Atmospheric Chemistry and Physics*; ANOVA, analysis of variance; *DSR*, *Deep Sea Research*; *JGR-B*, *Journal of Geophysical Research: Biogeosciences*; *JGR-SE*, *Journal of Geophysical Research: Solid Earth*; *NG*, *Nature Geosciences*; *PNAS*, *Proceedings of the National Academy of Sciences of the United States of America*.
[a]Number of papers used in this statistical analysis.
[b]One-way ranked ANOVA; see the methods and the results sections for details, looking at statistical differences between papers with the names of first authors suggesting a man, a woman, or a name from which the gender cannot be ascertained in terms of the time elapsed from paper submission to paper acceptance.

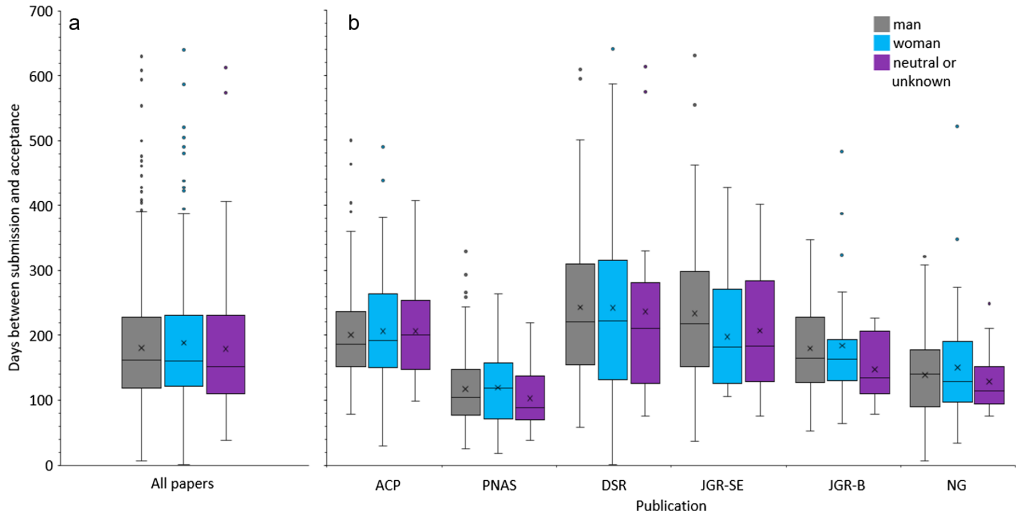

Figure 1. Variation in time (days) between article submission and acceptance for (a) all papers included in this study and (b) for papers submitted to the individual journals used in this study. See Table 1 for journal abbreviations. Box and whisker plots show the median (central line), mean (internal cross), and interquartile range (IQR, top and bottom of box). Outliers greater than 1.5 times the IQR (the whiskers) are shown as individual points. For colours, see inset legend.

ANOVA on ranks) difference between the length of time spent in review by papers with men, women, or those in the neutral/unknown group as first authors. This was true for the combined data set of all papers (Figure 1a) and also for each journal (Figure 1b). *P* values for these statistical tests are given in Table 3. That no statistically significant difference was seen even at the level of any individual journal allows us to conclude with some confidence that the results were not influenced by any of the following factors:

- Publication length, which is controlled in *PNAS* and NG but not in others.

- Journal turnaround times or protocols, which are more strictly controlled in *PNAS*, for example, than in *ACP*.
- Impact factor, the range for which is given in Table 1.
- Way of setting out the first name (either fully spelt out or shortened to initials), with initials being common in *ACP* but not used at all in *PNAS*.

Discussion

The serious imbalance between papers with men as first authors and those with women as first authors (overall men:women ratio of 2:1; Table 2) is not new,[13] but these recent results indicate a persistent problem, despite earlier publications reporting that the imbalance was decreasing in terms of individual career publication rates for men and women.[13] It is worth considering whether this imbalance in the number of publications is merely a reflection of the number of men and women in STEM academic jobs (more men in STEM positions would be reflected in a larger number of publications with men as first authors). However, the picture is more complex than this, with a sliding scale of gender inequality. The ratio of men:women scientists is roughly 1:1 at the doctoral degree level but becomes skewed as much as 5:1 at the professorial level.[14] There is some evidence that it is the early stages of an academic career that are the most productive (in terms of being first author),[15] a time when the gender ratio in research is more equal, suggesting that we cannot attribute this imbalance in the number of publications wholly to the difference in employment.
The lack of statistically significant difference between the time taken to review papers written by women and those by men also held true for papers published in 2006 (for all journals included in the study except NG and *PNAS*; see the explanation in the Section Methods) and those in 2016 (for all journals).

This result is reflected in other studies; for example, Duch et al.[16] found that in research disciplines with high research expenditure (such as molecular biology), the number of publications by women was consistently and significantly lower than that by men, which they linked to competition for resources. All the journals studied in this paper focus on research which is intensive in terms of physical resources and commonly involves both laboratory and field work – differences that may account for the gender imbalance seen here.

This study did not find a statistically significant difference between genders in terms of the time taken for peer review, which is consistent with an earlier study which reported that manipulating the gender of the first author (as signalled by the name) had no impact on the acceptance or rejection of the paper in question[17] in a biology-focused journal. On the other hand, our results are in contrast with those of a recent paper, which reported a significant difference between the time spent in peer review by papers written by men and those written by women in an economics-focused journal.[7]

This study does have its limitations: for example, it does not take into account all the aspects that are subject to bias. The analysis performed here was limited to papers that had been accepted and subsequently published. A recent Royal Society of Chemistry report highlights subtle biases throughout the publication process, including one that shows that papers authored by women are more likely to be rejected even before peer review,[18] so called 'desk rejection'. The study covered a narrow window of time (2006–2009 and 2016) and a limited number of papers from only six journals. Within these considerations, this study did attempt to establish that these results hold true regardless of other factors

such as the journal impact factor, ways of publishing first names (in full or only as initials), and the length of the paper – factors that were controlled for, to some extent, by a careful choice of the journals (see the Section Methods, which describes the basis for selecting the journals). This suggests that within these STEM journals, gender bias during peer review is not as strong as has been reported earlier.[17] It would also be of interest in future studies to compare, if possible, these results with those involving journals that follow a double-blind review process.

In conclusion, an analysis of a large number (approximately 1100) of papers from six journals representing diverse disciplines within the physical sciences showed that papers in which the first author's name indicated a woman did not differ significantly from those in which the name indicated a man in terms of the time taken for peer review, or the time between article submission and article acceptance. However, this study did find that men outnumbered women 2:1 in the number of papers published, an imbalance far wider than that between the ratio of men to women found at early and mid-career levels of STEM academic employment. As publications remain an important marker of academic progression, such serious imbalance should be addressed to help ensure a level playing field for academic progression.

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