Title:

Gender bias in (neuro)science: facts, consequences and solutions

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Main text:

Introduction
When advocating for gender equity in (neuro)science, adverse comments or reactions are not rare [1]. In this opinion paper, we aim at describing and addressing these comments as well as discussing the different approaches that can be taken at the institutional, organizational and individual levels to counter gender bias. We base our reasoning on empirical data but also on the reactions[a] collected after the release of our repository (www.winrepo.org), an initiative we started to increase the visibility of women in neuroscience.

"All this is not necessary"
The first remark was that 'all this' -referring to actions promoting awareness such as repositories of women in science or awards for women in STEM- was not necessary as gender bias is behind us. Unfortunately, there is ample evidence that it is not the case and that women's careers are still affected by gender bias.

FACTS
In society at large, women are paid less given the same degree and field of work as men [2]. The pay gap is also present in academia [3] and persists: for example, in 2017 the gender pay gap at University College London was 17.5%, close to the national average of 18% [4]. In the case of UCL, the gap also represented a lower proportion of females in the senior roles (only 37% females in the higher quartile pay grade). While proportions of students at the undergraduate level are roughly similar between males and females in STEM, the gap between male and female representation increases with seniority of the position [5,6]. This evidence displays that there are less women at senior positions in academia and that they are typically paid less than their male peers for equal skills[7]. Does this mean that women are less interested in pursuing a career in academia?

Absolutely not! The rate of career switching is indeed higher for female post-doctoral researchers who are planning to (or already) have children than for males in similar circumstances [8]. However, women meet a number of additional obstacles, preventing them from reaching more senior positions [9]. These include: a lower acceptance rate for papers with a female last author [10]; lower acceptance rate for funding [11–13]; lower rate of invitation to conferences or workshops [14](https://biaswatchneuro.com/) and lower chances of being hired for tenure-track positions at the same competence level [15,16]. Part of these obstacles may be further sustained by the under-representation of women in the peer-review process [10] and on deciding bodies, as there is a tendency for homophily, i.e. a same-gender bias, for both men and women [17].

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[a] Verbal comments collected during the Organization for Human Brain Mapping 2018 meeting as well as from sitting on the organization committees of different events.

In neuroscience, women are under-represented in various aspects of academic life (Figure 1): females are awarded significantly less prizes than males (p=1.0539e-05, n=23), there are significantly less papers with a female first (p=3.9590e-04, n=1760) or last author (p<e-20, n=1760), women appear significantly less in seminar series (p=3.9355e-17, n=38) and conferences (as invited or contributed talks, p=5.7349e-80, n=295). Please see the methods for details on data collection and analysis.
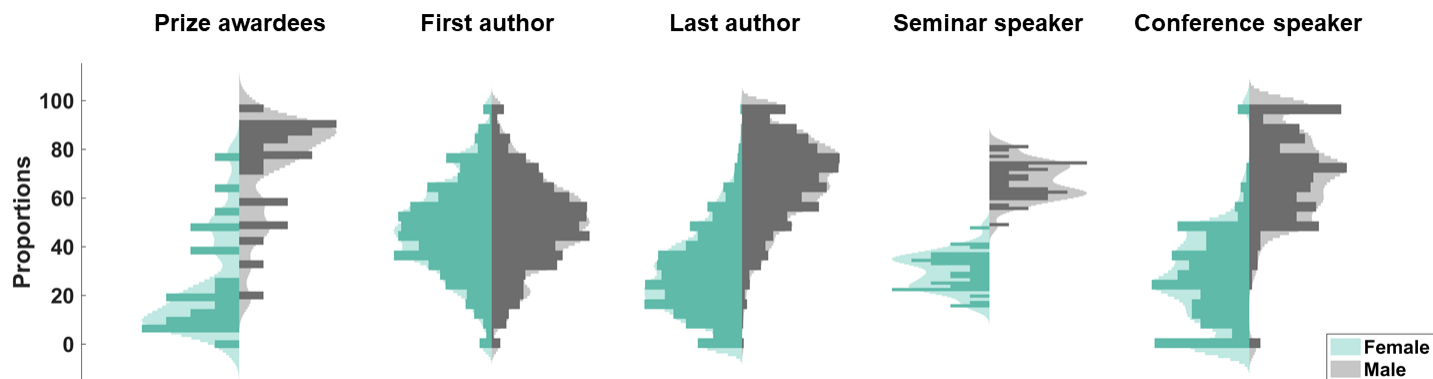
Figure 1: Proportions in % of females (green) and males (gray) in different aspects of neuroscientific academic life.

CONSEQUENCES
"As long as the job is done..."
The second comment we received was "I don't really care if there is a bias as long as the job is done." Unfairness set apart, this argument does not hold in research and academia. Indeed, research is a creative process and Woolley et al. [18] have shown that the collective intelligence of a group depends on the proportion of females in this group. Indeed, diverse teams outperform homogeneous groups in innovation, flexibility, problem-solving, and decision making[19].

In addition, when a group is underrepresented, the issues relevant to this group are not addressed as much. For example, women's health has been less studied than male health as women were less represented in (or even excluded from) clinical trials [20]. Another example (based on ethnicity bias) is that black men accepted more treatment and more invasive or preventive care when seen by a black doctor [21]. Assessing and preventing bias is important not only for the affected groups, but also for the population as a whole: Holdcroft [22] showed that studying female and male groups separately instead of mixed in (un)equal proportions would highlight specific traits in each gender, which could provide better treatments/prevention techniques for all.

Another interesting consequence is that as a result of existing biases, artificial intelligence is biased as well. When trained on a large corpus of text, a machine learning model will associate man with doctor and woman with nurse, or man with engineer and woman with homemaker [23]. A new field of research is now dedicated to try to correct for this bias (e.g. FATE at Microsoft, https://www.microsoft.com/en-us/research/group/fate/). As machine learning for health data is becoming increasingly popular, we need to ensure that the same type of bias (e.g. due to biased experimental designs) will not influence the model's outcome as this would limit the use of such technology in 'real' clinical settings.

SOLUTIONS
Based on these facts, we see that addressing gender bias would be beneficial for all. In practice, most of us are implicitly subject to biases [24,25]. Solutions have been proposed to address different aspects of gender bias, at the institutional, organizational and individual level (summary in Table 1).

Institutions	Organizations	Individuals

• Organize bias training sessions • Actively collect data to define new policies • Implement quotas (cascading model for hires) • Consider gender balance when awarding prizes or fellowships (e.g. through tandem nomination)	• Favor diverse proposals • Ensure all organizing committees and reviewer pools are gender-balanced • Search for candidates on lists or repositories • Consider gender balance when awarding prizes or fellowships (e.g. through tandem nomination) • Provide childcare or other family-friendly measures	• Be aware of your and others' bias (take a test here https://implicit.harvard.edu/implicit/) • Attend bias training sessions • Speak out when observing gender biased events/behaviors • Sign up on repositories or encourage female colleagues to do so • Submit recommendations for female scientists (directly to organizations or on repositories)

Table 1: Summary of actions that can be taken at the institutional, organizational and individual levels to promote diversity in the field.

At the institutional level

As mentioned in Asplund and Welle [24], universities, funding agencies and scientific journals have an important role to play. As examples, universities can organize bias training sessions for male and female scientists to raise awareness [24] and scientific journals can implement double-blind reviewing to mitigate any potential gender bias during review [26]. All institutions can also collect data on various aspects of their functioning (e.g. student enrollment, reviewing panels, etc.) to establish new policies to drive gender balance.

One popular strategy in this respect is to introduce gender quotas, regulations that require a certain proportion of females in a given position (for example percentage of new hires over a certain period of time, invited speakers at conferences, winners of an award). Quotas can be binding (i.e. with consequences in case of non-compliance) or voluntary (also referred to as *targets*). They were introduced in various domains of the general society to counterbalance male dominance (e.g. in politics). As in all processes that aim at correcting a bias, a larger counter-effect needs to be imposed to obtain equilibrium. In this sense, quotas have also been referred to as 'positive discrimination' and are seen as a temporary process to obtain gender balance after a 'transition period'.

In academia, quotas can be implemented in a variety of ways [27]. For example, a *cascading model* can be encouraged for new hires, where the quotas reflect the proportions of female candidates at the level below the open position. Another example is the Hans Fischer fellowship scheme that requires *tandem nominations*, where each institution must suggest two candidates for a fellowship, one being female [b]. Quotas have elicited many reactions, which we discuss below.

"**Quotas are unfair**"

This type of comment reveals a deeper concern: will these measures lead to the opposite situation, where women are favored independently of their skill levels? This concern may also be associated with a fear of increased competition.

As mentioned above, women face more obstacles as compared to male colleagues, which tends to result in less competitive resumes. It is hence likely that for equal resumes, women scientists are actually more qualified and/or experienced. Furthermore, skill judgment is subjective: studies have shown that males will be more quickly assessed as qualified or hirable than women [15,28,29]. Based on these two parameters, favoring a woman over a man with 'equal competence' very probably means to hire the best candidate.

The fear about increased competition is nonetheless true: with more women scientists being visible, there are more suitable candidates for the same job. Besley et al. [30] have however shown that only underqualified men could potentially be displaced. Hence, quotas and the increased presence of women on job market should

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[b] https://www.ias.tum.de/fellowship-program/hans-fischer-fellowship/

not worry men that are a good fit for the job in question. The authors have further reported an increase in the overall level of competence of a team after quotas were introduced [30], suggesting that quotas can be beneficial for the project/institution as a whole.

"**Was I selected because of the quotas?**"
This point was specifically made by women scientists: quotas tend to hurt their self-confidence, as the value of their work may be questioned, and the reason for their success be attributed to their gender (also mentioned in [1]). Unfortunately, we do not have the answer to this question. However, given the evidence discussed above, it is unlikely that an unqualified woman would be given an opportunity. We would also like to stress that, whatever caused the opportunity, women in positions of power can act as role models, which will eventually attract more women and lead to a more diverse field.

As we have seen, quotas are a popular measure in place to increase diversity in institutions. They are now also present at the organizational level, especially at conferences.

At the organizational level - Conferences
Diversity of speakers is becoming a criterion in the selection of keynote lectures, symposia, workshops or educational courses at conferences. Typically, no well-defined numbers or proportions of female speakers are enforced, but proposals with an appropriate representation of minorities are favored (e.g. Society for Neuroscience call for symposia[c], Organization for Human Brain Mapping educational courses[d]). Organizers are however not always able to submit diverse proposals. The reasons cited are multiple:

"There are not many female scientists in this field"
As mentioned before, there are indeed less women at more senior positions than men. However, an event typically has a few numbers of speakers and there should almost definitely be at least a few female scientists in that domain. In terms of absolute numbers, it hence seems feasible to find suitable female candidates for invited speaker, program committee member, etc.
On the other hand, women are also less visible than men and when women become visible, a same small circle of women tend to be invited to all events.
To help with this issue, multiple initiatives have been created, mostly as lists or repositories of women in science. In brain science, more than 1500 women from all countries and levels of seniority are registered on the following lists: Anne's list (https://anneslist.net/), Women in Brain stimulation (http://womeninbrainstim.com/), 500 women scientists (https://500womenscientists.org/) or the Women in Neuroscience Repository (www.winrepo.org). We believe these resources can be helpful when searching for suitable female candidates but acknowledge that using repositories requires more effort (finding candidates, checking their references and publications) than sending an invitation to someone already known to us. To mitigate this issue, some initiatives (www.winrepo.org) now include a 'recommendation system', where all scientists can leave a comment after having attended a talk by a female neuroscientist member of the repository.

"All the women we invited declined"
Although Nittrouer et al. [14] demonstrated that women did not decline more talk invitations than men, this was a quite common remark (discussed in [1] as well). To avoid this situation, we recommend inviting women that are outside the small circle of repeatedly solicited scientists. Mentioning which (bundle of) work in particular elicited this invitation could potentially help avoid the question "Why was I invited?". More generally, pointing out the contribution of the scientific, professional or educational background of the researcher in the symposium or educational event could help clarify for attendees and invited researchers the legitimacy and relevance of the speaker's inclusion.

While we hope that the imperfect solution of quotas [31] is temporary, they should be considered not only when inviting keynote speakers to an event: the organizing committee of events should be gender balanced, as well as the reviewer pool and the program committee. This also applies to awarding prizes. Finally, we believe that

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[c] https://web.sfn.org/SfN/Annual-Meeting/Neuroscience-2018/Sessions-and-Events/Proposals-for-Symposia-and-Minisymposia
[d] https://www.humanbrainmapping.org/files/2019/Educational%20Course%20Guidelines.pdf

a representation of women that is equivalent to the base rate in the field might lead to status quo and we therefore advocate for truly gender-balanced events. These measures, when successfully implemented, can lead to a more diverse representation, as in the example of the annual meeting of the American College of Neuropsychopharmacology [1].

Break down the barrier for women attendance
Attendance of women in scientific international events is crucial for the networking, visibility and dissemination that underlie the development of a research career. However, the critical period encountered in the "junior" phase frequently coincides with the period of pregnancy for women and early age children care in general for both genders. The difficulties for parents, in particular women who breastfeed, to attend conferences have been highlighted several times. Calisi and a Working Group of Mothers in Sciences [32] have discussed these difficulties and already made clear concrete suggestions referred to as "CARE" for 1) Childcare, 2) Accommodate families, 3) Resources, 4) Establish social networks. Offering childcare at conferences is the first and probably the most important recommendation for conference organizations. We however acknowledge that the cost of childcare facilities can make it unaffordable for many small conferences. Independently of child care facilities, all conferences should accommodate families, for example by promoting children's attendance at conference dinners. Additional facilities should be organized for breastfeeding women, such as dedicated rooms and fridges for expressed milk. Society for Neuroscience can be pointed out as an example of fruitful endeavor in that regard. Finally, while all those facilities require small or larger financial/material investment, conferences can organize social networks platforms for parents to self-help as a community. Such platforms have the additional benefit of becoming a networking opportunity for parents with young children.

Thus, overall, several complementary initiatives appear as solutions at the institutional and organizational levels. Nevertheless, a society cannot evolve at the institutional level without parallel evolution of individuals' mindset and effort. A collective is made of individuals, who each have the ability to raise awareness on gender bias and foster diversity in their organization.

At the individual level
All scientists can contribute to a more diverse field. When invited to an event, one can check the diversity in the organization and target audience of the event. Both men and women have previously declined to speak at certain events that were obviously gender biased (also see this pledge not to serve on all male panels[e]). In this case, we believe the answer should be constructive, with a list of suggested female candidates. We also found that using interrogation could communicate the issue without being accusing (e.g. "I cannot locate the name of the female speakers for this event. Are you still awaiting responses?").
To ease the selection of female speakers for events or other opportunities, one can also consider submitting recommendations for female scientists, as on the Women in Neuroscience Repository (www.winrepo.org).

Beyond conference organization, diversity should also be promoted for other scientific activities, such as when looking for collaborators for projects or in grant writing.

Some organizations or individuals have also launched specific initiatives to target gender bias in their field. A successful example is the 'Women in Machine Learning Workshop' (https://wimlworkshop.org) that evolved from a side event at a renowned machine learning conference to an organization with chapters in many parts of the world.

All female events
It is however easy with events targeting gender bias to encounter an opposite problem: male under-representation. While potentially beneficial for women (especially in terms of networking), all female events do not make a good job at addressing the issue of implicit gender bias. Indeed, discussing gender bias with only the affected community cannot solve the problem (e.g.[f]). These all female events also tend to exclude men attendees while there are still many more men in positions of power. Ignoring the difference these men could

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[e] https://www.genderavenger.com/pledge/
[f] www.theguardian.com/women-in-leadership/2013/jul/03/why-i-wont-speak-at-women-only-events

make if they were promoting diversity in their field is hindering changes in this direction. Thus, both men and women could foster evolution by attending such events.

Fighting together for gender equality
In the fight for gender equality, there are no sides and men can be the allies of women[g]. Non-constructive or blaming statements, whether true or not, only hurt the discussion. We, the present generation of neuroscientists, men and women, have the responsibility to provide an equal-opportunity field for the coming generations.

Conclusion
We have outlined evidence showing the existence of a gender bias in (neuro)science and proposed some possible solutions at different levels. Whether action is taken at the institutional, organizational or individual level, we would like to emphasize that addressing gender bias should always be approached in a non-blaming manner (unless in the case of clear misconduct or conscious discrimination).
Finally, we would like to conclude on a positive note: although there is still a long way to go to change the male dominant culture, there is a rise in awareness of the problem and the situation is improving [7,33] (Figure 2). We firmly believe that pursuing the current efforts while bringing men and women together will be the key towards a fairer and more creative research community.[h]
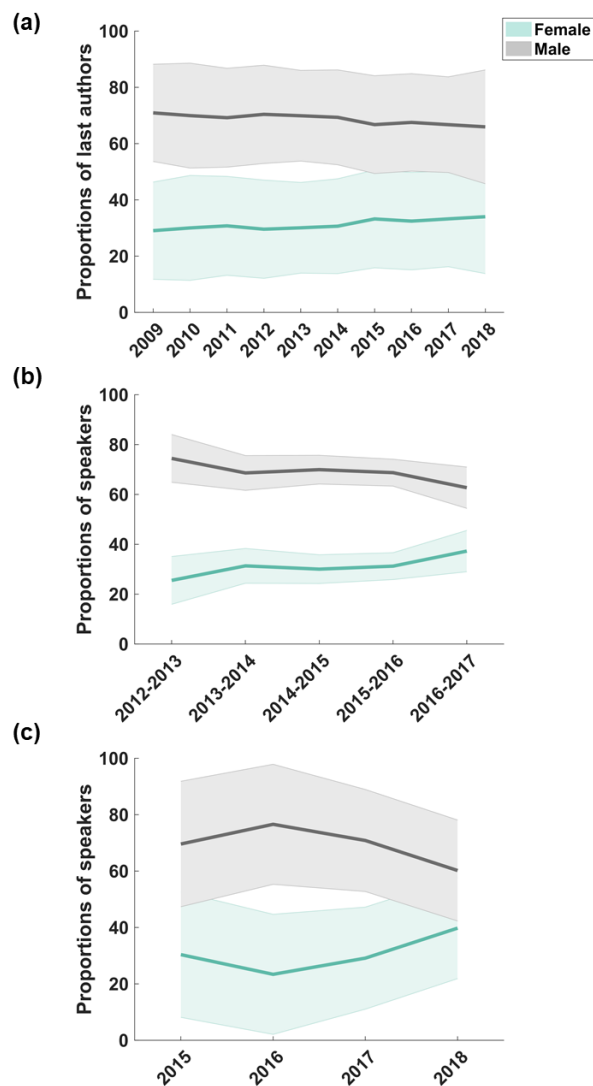
Figure 2: Proportions of females (green) and males (gray) as (a) last authors of journal papers, (b) invited speakers in seminar series, and (c) speakers (invited or contributed) at conferences over the years. Plots represent averages with ± 1 standard deviation.

Methods

Data

Prize awardees

Data was collected from BiasWatchNeuro[i,j] on male and female award recipients, including early career awards. In addition, we manually collected data from other awards to obtain a total of 23 awards, each being distributed for an average of 12 years (minimum: 4 years, maximum: 59 years). The gender of each awardee was determined by manual inspection of the person's institutional profile.

Authors

Data was collected from the NIHReporter[k]. For each year between 2009 and 2018, all publications relating to the term 'neuroscience' were selected, leading to about 15000 publications per year. For each publication, we extracted the first name of the first and last authors. For each name, we used the Genderize.io API [l] to identify the gender of the names. We then limited the data set to articles for which the gender of the first and last author was returned as 'male' or 'female' by the API. We aggregated the results by journals and only included journals that had at least 5 such publications for each of the last ten years. This led to the final selection of 176 journals.

Seminar speakers

Data was collected from an article published on BiasWatchNeuro[m] reporting the speaker gender ratio for 8 seminar series. Missing data was filled manually, identifying the speaker gender based on their institutional profiles. Each seminar had data for 4 (n=2) or 5 (n=6) academic years.

Conference speakers

Data was extracted from BiasWatchNeuro by scraping all articles related to conferences and workshops and identifying the 'speaker gender ratio'. When multiple ratios were reported (e.g. 'keynote speaker gender ratio' and 'total invited speaker ratio'), the last line was selected as it typically referred to overall counts. This led to the selection of 295 events between 2015 and 2018, for which the number of male and female speakers were extracted. Please note that the year associated to each event was the date of article publication on BiasWatchNeuro and might not correspond to the year of the event.

Distributions

For each point in a data set, the proportions of females (females / males+females) were computed (in %) and plotted as histograms overlaying the corresponding violin plot for all data points (Figure 1). The derived male and female proportion distributions were tested for potential differences using a Kolmogorov-Smirnov test. In addition, the evolution over the years was plotted as the average (± 1 standard deviation) across the data points recorded in each year (Figure 2).

Acknowledgments

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[i] https://biaswatchneuro.com/2016/08/17/no-prize-worthy-women-2/

[j] https://biaswatchneuro.com/category/other/

[k] https://projectreporter.nih.gov/reporter.cfm

[l] https://github.com/SteelPangolin/genderize

[m] https://biaswatchneuro.com/case-studies/seminar-series/

[n] https://anneurai.net/2018/01/28/gender-diversity-in-academia/

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