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GENDER-RELATED DIFFERENCES IN SCIENTIFIC COLLABORATION DEPEND ON WORKING CONDITIONS

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Abstract

The presented study examines differences in data sharing and scientific working behaviour between male and female researchers. To understand the context of our study, it has to be said that articles and data – as the raw material for non-theoretical publications – are crucial for an individual researcher's career development. Examining the data sharing behaviour is therefore a good proxy to examine differences in male and female working behaviour in a competitive environment.

Our study is based on a survey among 1321 (mainly German) researchers. Overall our results suggests that the working conditions in the form of gender distribution and relevance of research data in different scientific fields are better predictors for sharing behaviour than the gender of the individual researcher. Furthermore, the findings provide first insights in the complex underlying factors of gender equality in science that should be addressed by future research.

Keywords: Gender, collaboration, data sharing, implicit stereotypes, scientific domains.

1 INTRODUCTION

In the last two decades, the gender movement has been gaining momentum. However, despite the policies and regulations implemented by policy bodies and science funders, gender differences in science and structural disadvantages for women in science prevail (see for example [1]).

Here, we examine gender-related differences in the scientific working behaviour, in particular differences in the data sharing behaviour between male and female researchers in male and female domains. To understand the context of our study, it has to be said that research data are – as the raw material for article publications – crucial for the individual researcher's career development. Accordingly, academia can be described as a reputation economy [2], i.e., a system in which each researcher tries to maximize his/her reputation. Researchers share data and knowledge rather if it pays off in terms of reputational gain. There is a broad consensus that better access to research data is good scientific practice and beneficial for the scientific progress (e.g., using secondary data in meta-analyses) and self-regulation (e.g., replication studies). Researchers see the potential of data sharing for scientific progress but still act contrary to the common benefit [2]. This situation can be described as a social dilemma because for the individual researcher data sharing implicates high costs (e.g., effort for providing data in a reusable form, danger that others might publish before them) but comparable minor benefits for the scientific career [3]. Data sharing is therefore a good proxy to examine gender-related differences of collaborative behaviour in a competitive working environment.

Numerous studies have examined the collaborative behaviour of male and female researchers. Massen and colleagues [4] showed the presence of male-exclusive sharing networks in science and a generally more prosocial behaviour between male scientists. Balliet and colleagues [5] made a similar observation in a meta-analysis on sex differences in general cooperative behaviour. Besides, also the so-called "old boy" networks might influence the cooperative behaviour of males and females in academia [6]. Drawing only from these results, one could conclude that female researchers collaborate less than male researchers. However, when examining the working behaviour of male and female researchers, also the social and cultural context must be taken into account. Numerous studies show large gaps between women and men in terms of the decision-making positions held in science and access to funding [1] [7] [8]. Thus, the reluctance to collaborate could be a viable competitive strategy in a male dominated environment.

Another factor of influence might be implicit social cognition [9], namely implicit gender stereotypes which in turn can affect behaviour (e.g., [10]). Several studies showed an implicit association for male with math and science on the hand and females with fine arts and languages on the other hand [11].

Thereby, it has to be said that implicit stereotypes can be altered by promoting counter-stereotypes [12] [13]. Indeed, several studies showed that female students in STEM fields hold weaker implicit gender-math stereotypes than their male counterparts [14] and male and female humanities students [15]. Additionally, also metacognition can influence stereotyped judgements. If individuals have metacognitive insights in the gender stereotypes, they are able to avoid and counteract gender stereotyping [16] or even can overcorrect it [17] [18].

Against this background, we investigate two research questions (RQ) on gender differences in the working behaviour of male and female researchers: First, are there gender-related differences in the working behaviour between male and female researchers when it comes to publishing articles and sharing data? Second, what role do the specific working conditions play, namely the relevance of research data and the gender distribution in different scientific fields?

2 METHODOLOGY

2.1 Aim of the Study and Research Questions (RQ)

In order to investigate gender-related differences in scientific working behaviour, we analysed on the one hand generally (across all domains, see RQ1) different aspects of "openness" connected with scientific working behaviour, namely article publication behaviour, data sharing practices, and secondary data usage. On the other hand, we wanted to receive more detailed insights in the influence of the circumstances of the working domain (see RQ2) in relation to two aspects: First, if a domain is predominantly male or female (hereinafter called "gendered domain"). Second, if research data are highly important for the scientific career (hereinafter called "data-driven domains").

The differentiations of the latter question (RQ2) are important since gendered domains on the one hand and data-driven domains on the other hand are often confounded. Typical male domains like physics are strongly data-driven whereas typical female domains like languages are less data-driven [19] [20]. Additionally, in relation to implicit stereotypes, it should not only be considered if a discipline is predominately male or not (by merely looking if there are more males or females), but it should also be borne in mind how visible and salient the gender disparities are. That means, for domains with a very large difference in the gender distribution (like in the STEM fields), the gender disparities are more visible which in turn can enhance the consciousness of gender stereotypes and as a result can trigger counter-stereotypical behaviour.

In this light, we focused separately on different female versus male domains. For female domains we differentiated additionally between female domains in which the career and the scientific work is strongly interconnected with research data (data-driven female domains) and female domains in which the work with research data has a relatively low importance (female domains with a low relevance of research data). The latter can provide first insights if the data sharing behaviour is solely influenced by gendered domains or if the relevance of research data for the career might be a critical factor as well. For male domains we differentiated between male domains with a highly visible gender gap (i.e., a strong overbalance of male researchers in relation to female researchers) and male domains in which the gender gap is rather low (i.e., there are substantially more males but the overbalance is rather low). This differentiation (high / low visibility of the gender gap) was made to account for possible implicit gender stereotypes and the ongoing discussion about the STEM fields in which women are only a very small minority and thus received special attention and support.

(Remark: Theoretically, it would be also interesting to analyse female data-driven domains with a strong overbalance of female researchers and male domains with a low relevance of research data. However, practically we could not identify such domains.)

For the identification of data-driven domains, i.e., domains that are strongly based on research data and in which the career of researchers depends strongly on the work with research data (including publishing with research data) we relate to Borgman [19] [20].

For the identification of female versus male domains (of our predominantly German sample) we used the information of Federal Statistical Office of Germany (https://www.destatis.de/EN/ AboutUs/ AboutUs.html) about the gender distribution of the university staff of different domains. We calculated the ratio between males and females and used the following heuristic rationale for the definition of male versus female domains:

A domain was qualified as “female domain” if the ratio male to female was equal or lower 3:4. A domain was qualified as “male domain” if the ratio male to female was equal or higher 4:3. A domain was qualified as a “male domain with a highly visible gender gap” (i.e., where the unequal gender distribution was extreme and thus highly visible) if the ratio male to female was equal or higher 3:1.

Based on this rational we identified the following research domains for the analyses of our data sample:

- Female data-driven domains: psychology, education
- Female domains in which research data have only a minor relevance for the academic work and career: languages, literature
- Male data-driven domains with a highly visible gender gap: math, physics, engineering, computer sciences
- Male data-driven domains with a less visible gender gap: history, geology, chemistry, economics

Taken together, the two main research questions of our study were as follows:

RQ1: Are there gender-related differences in the scientific working behaviour in relation to different indicators of openness and collaboration?

Thereby, we investigated the following indicators of scientific working behaviour: *Article publication behaviour* (including open access; importance of impact factor, and importance of fast publication), *data sharing behaviour* (including attitudes towards open data, conditions of data sharing, and actual data sharing in the past), and *secondary data usage* (including actual secondary data use, conditions of secondary data use, and aims of secondary data use).

RQ2: How differs the scientific working behaviour of female versus male researchers in different female versus male domains?

Based on the considerations reported above we analysed (as already mentioned) the following four groups of domains: Female data-driven domains (psychology, education), female domains in which research data have only a minor relevance for the academic work and career (languages, literature), male data-driven domains with a highly visible gender gap (maths, physics, engineering, computer sciences), and male data-driven domains with a less visible gender gap (history, geology, chemistry, economics).

2.2 Measurement Instrument: Online Survey

The data were assessed by the help of an online survey. The survey contained mainly closed multiple-choice questions as rating scales and covered questions on socio demographic data, the individual working context, publication preferences, and data handling practices (questionnaire available from: https://github.com/data-sharing/persistent/tree/master/dsa-03/). For the distribution, we contacted 60 German universities and the four biggest German research organizations, the Max Planck Society, the Leibniz Association, the Helmholtz Association and the Fraunhofer Gesellschaft, and uploaded a link to the survey on our project website and on the website of the German Data Forum. That being said, our sample is a convenience sample and not representative of the entire population of academic researchers in Germany or worldwide.

2.3 Measurement of Variables

For the analyses, we used gender as independent variable. Gender was assessed by a multiple choice item (together with other socio demographic data) at the end of the survey. To identify the working domain, we used the open answers on the specification of the participants’ concrete working discipline. The answers were coded in relation to the categories of the Federal Statistical Office of Germany (https://www.destatist.de) used for the official statistics of the gender distribution of German researchers working at the university in different subjects. This allows us to identify domains (by the heuristic rational described above) with an overbalance of male or female researchers, respectively.

As mentioned in the RQs we investigated the influence of gender on the scientific working behaviour in relation to three aspects (groups of dependent variables): Article publication behaviour, data sharing behaviour, and secondary data use.

For the assessment of the *article publication behaviour* we asked our participants for the importance of three different aspect of publishing, namely, the importance of open access, the importance of reputation/impact, and the importance of fast publication. The participants had to rate how important theses three aspects were for them on a 5-point Likert scale from 1 (not important at all) to 5 (very important). Additionally, the answering option “don’t know” option was provided.

The variables on *data sharing behaviour* included three different aspects: the attitude towards data sharing, the personal necessary conditions of sharing, and the actual data sharing in the past. The attitude towards data sharing was measured by the rating of the statement ”researchers should generally publish their data” on a 5-point Likert scale from 1 (strongly disagree) to 5 (agree completely). Additionally, a “don’t know” option was available. The personal necessary conditions of data sharing were measured by a multiple choice item. The participants had to indicate under what conditions they would share their research data. The possible answering options were: unconditionally, on demand, based on specific use agreement, not at all. For the measurement of the actual data sharing in the past the participants had to indicate if they had shared their data with specific target groups or not. The six different target groups were: researchers they personally know, researchers from their own institute/organization, researchers with a similar topic, all non-commercial researchers, commercial researchers, and the public. Based on the answers, we calculated two derived dichotomous variables: First, the “basic sharing”, i.e., if they had shared their data with at least one of the target groups. Second, the “extensive sharing”, i.e., they had shared with a broad audience, i.e., with the public or/and all non-commercial researchers.

The variables on *secondary data use* were assessed by rating-scales. On the one hand, the participants had to rate the (personal) importance of different aspects when using secondary data, namely that the secondary data are from reliable person/organization, relevant articles have already been published with the data, the data collection is documented comprehensively, the data are easy to use for them, and there is a contact person available for questions. On the other hand, the participants had to indicate for what purpose they would like to use secondary data. Accordingly, we assessed two ratings, namely to use secondary data for their own research and to use secondary data to replicate and verify research data. All ratings of the variables of secondary data use were made by means of a 5-point Likert scale ranging from 1 (does not apply at all) to 5 (applies completely). Additionally, a “don’t know” option was available.

Furthermore, we included the following *control variables*: sensitivity of research data, academic degree, years of working experience, age, if data sharing is common in the own discipline, and the knowledge about data sharing (knowledge where to find and knowledge how to share).

2.4 Description of the Sample and Analysis of Control Variables

Overall, 2661 people started the questionnaire, but not all respondents finished it. We excluded respondents who did not answer any questions about their status, employer and discipline and those who had answered less than 20% of the questions. We were left with 1564 valid entries.

We had no forced answers in the survey. Thus, the number of valid cases is partly differently for the variables, namely, only 1321 participants indicated their gender (as necessary prerequisite for the analyses of RQ1 and RQ2). Thereby the sample for the reported analyses comprised 750 males and 571 females. The average age of the respondents was 38 years. The analyses of the control variables delivered no additional insights and thus will not be reported here.

3 RESULTS

3.1 Rational of Data Analysis

The interval-scaled dependent variables were analysed by ANOVA. The groups of variables that were answered together (importance of open access, fast publishing, and impact factor; importance of different aspects when using secondary data; purposes of the use of secondary data) were analysed together by means of a MANOVA to account for the interdependencies between these variables. For the analysis of nominal-scaled dependent variables (willingness to share and actual sharing) we use cross tables and the Chi² test.

The four groups of domains (see RQ2) were analysed separately for gender-related differences. The analyses for each domain group were identical and analogous to the analyses of RQ1. This enabled a comparison of the pattern of findings of the whole sample and the identified subsamples of gendered domains.

Remark: *We selected only some domains and the selected domains are varying in three aspects: if it is a male or female domain, if the gender gap is highly visible, and if the domain is data driven. However, it was not a systematic variation of these three aspects (because this was practically not possible since, e.g., female domains with a highly visible gender gap do not exists) and the selected domains were not directly comparable. Thus, we made separate analyses instead of using an interaction model.*

3.2 Results on RQ1: Gender-Related Differences in Scientific Working Behaviour

3.2.1 Publication Behaviour

The analyses of the questions on publication behaviour (see table 1) reveal that fast publication is significantly more important for females compared to males ($F = 14.216$; $p < .001$). For the importance of open access and reputation/ impact no gender-related differences were found.

Table 1. Article publication behaviour – importance of different aspects.

	Male		*Female*		*All*	
	n	*M (SD)*	*n*	*M (SD)*	*n*	*M (SD)*
Open access	705	3.04 (1.32)	508	3.16 (1.27)	1213	3.09 (1.30)
Reputation / impact	705	4.15 (1.04)	508	4.19 (0.98)	1213	4.17 (1.02)
Fast publishing	705	3.37 (1.04)	508	3.59 (0.98)	1213	3.47 (1.02)

3.2.2 Data Sharing Behaviour

For the general attitudes towards data sharing (see table 2) females showed lower agreement that researchers should share ($F = 16.564$; $p < .001$). Asked for the personal necessary conditions of data sharing (see table 3), females reported less often about unconditional sharing and more often that they would share based on a specific use agreement (Chi² = 71.475; $p < .001$). Females shared also generally (see table 4) less often than males (Chi² = 27.066; $p < .001$). Females reported also about less actual data sharing with the public or/and non-commercial researchers (see table 5) in the past (Chi² = 35.077; $p < 001$).

Table 2. Attitude towards data sharing – agreement to the statement „researchers should generally publish their data“.

	Male		*Female*		*All*	
	n	*M (SD)*	*n*	*M (SD)*	*n*	*M (SD)*
Attitude data sharing	735	4.21 (0.98)	558	3.99 (1.00)	1293	4.12 (1.00)

Table 3. Conditions for data sharing.

Answering categories		*Male*	*Female*	*All*
Unconditionally	Obs	231	70	301
	Exp	170.7	130.3	301.0
	Std. Res	4.6	-5.3	
On demand	Obs	248	202	450
	Exp	255.1	194.9	450.0
	Std. Res	-0.4	0.5	
Based on a specific use agreement	Obs	263	296	559
	Exp	316.9	242.1	559.0
	Std. Res	-3.0	3.5	
Not at all	Obs	3	1	4
	Exp	2.3	1.7	4.0
	Std. Res	0.5	-0.6	
All		745	569	1314

Table 4. Basic data sharing in the past with at least one of the target groups (all domains).

Answering categories		*Male*	*Female*	*All*
No basic data sharing	Obs	100	140	240
	Exp	136.1	103.9	240.0
	Std. Res	-3.1	3.5	
Actual basic data sharing	Obs	644	428	1072
	Exp	607.9	464.1	1072.0
	Std. Res	1.5	-1.7	
All		744	568	1312

Table 5. Extensive data sharing in the past with the public and/or non-commercial researchers (all domains).

Answering categories		*Male*	*Female*	*All*
No extensive data sharing	Obs	528	482	1010
	Exp	572.7	437.3	1010.0
	Std. Res	-1.9	2.1	
Actual extensive data sharing	Obs	216	86	302
	Exp	171.3	130.7	302.0
	Std. Res	3.4	-3.9	
All		744	568	1312

3.2.3 Secondary Data Use

In relation to secondary data use (see table 6), females reported significantly less often that they have ever used secondary data ($Chi^2 = 8.878$; $p = .003$). Additionally, nearly all conditions for secondary data use (see table 7 top) were significantly more important for females, i.e., for females it is more important (compared to males) that secondary data come from reliable person/organization ($F = 9.843$; $p = .002$), the documentation of data collection is comprehensible ($F = 17.874$; $p < .001$), the data are easy to use ($F = 6.141$; $p = .013$), and a contact person is available for questions ($F = 32.368$; $p < .001$). However, there was no gender-related difference for the importance of the condition that relevant articles have already been published. In relation to the purpose of secondary data use (see table 7 bottom) we found no gender-related differences.

Table 6. Secondary data use in the past.

Answering categories		Male	Female	All
No	Obs	209	203	412
	Exp	233.8	178.2	412.0
	Std. Res	-1.6	1.9	
Yes	Obs	535	364	899
	Exp	510.2	388.8	899.0
	Std. Res	1.1	-1.3	
All		744	567	1311

Table 7. Conditions of secondary data use and purpose of secondary data use.

Item	Male		Female		All	
	n	M (SD)	n	M (SD)	n	M (SD)
Reliability of the person / organization	663	4.62 (0.70)	494	4.74 (0.57)	1157	4.67 (0.65)
Relevant articles have been published	663	2.93 (1.36)	494	3.00 (1.39)	1157	2.96 (1.37)
Comprehensiveness of data documentation	663	4.51 (0.74)	494	4.68 (0.63)	1157	4.58 (0.70)
Ease of use	663	3.74 (1.04)	494	3.89 (1.02)	1157	3.80 (1.03)
Availability of a contact person	663	3.35 (1.04)	494	3.75 (1.13)	1157	3.52 (1.23)
Purpose: own original research	663	4.41 (0.85)	494	4.45 (0.82)	1157	4.43 (0.84)
Purpose: verifying / falsifying research results	663	3.26 (1.31)	494	3.26 (1.36)	1157	3.26 (1.33)

3.3 Results on RQ2: Influence of Gender in Different Domains

<u>Remark:</u> *For a better readability and in face of the limited space we omitted the tables with the descriptive statistics for RQ2. The interested reader can contact the first author for the complete descriptive statistics for RQ2.*

3.3.1 Female Data-Driven Domains

For female data-driven domains we found no significant gender-related differences for the publication behaviour. However in relation to data sharing, females agreed significantly less ($F = 9.266$; $p = .003$) that researchers should share. Additionally, females are less willing to share unconditionally ($Chi^2 = 10.574$; $p = .005$) but more on demand and based on specific use agreements. Females reported about less actual data sharing in principal ($Chi^2 = 5.832$; $p = .016$) and less actual data sharing with the public/non-commercial researchers ($Chi^2 = 3.984$; $p = .046$). For secondary data use we found no gender-related differences for secondary data use in the past. For the conditions of secondary data use we found only a gender-related difference in the form that it was more important for females (compared to males) to have a contact person available ($F = 9.089$; $p = .003$).

3.3.2 Female Domains with Low Relevance of Research Data

Four this group of domains we found no gender-related differences, neither for publication behaviour nor for data sharing behaviour, nor for secondary data use.

3.3.3 Male Data-Driven Domains with a Highly Visible Gender Gap

In male data-driven domains with a high visibility of the gender gap, females reported a significantly higher importance of open access of publications ($F = 9.918$; $p = .002$). In relation to data sharing and secondary data use we found no gender-related differences.

3.3.4 Male Data-Driven Domains with a Low Visibility of the Gender Gap

For male-data driven domains with a rather low visibility of the gender gap fast publications were significantly more important for females ($F = 5.038$; $p = .026$). Additionally, females agreed less that researchers should share their data ($F = 15.965$; $p < .001$). For the conditions of sharing, females were less willing to share unconditionally ($Chi^2 = 7.914$; $p = .048$) but more on demand. For the actual principal sharing there were no significant differences for gender. However, females reported about less actual data sharing with the public / non-commercial researchers ($Chi^2 = 8.146$; $p = .004$). For secondary data use, we found only for the conditions of secondary data use gender-related differences. For females a comprehensible description of the data was significantly more important ($F = 3.975$; $p = .047$). Additionally, there was a non-significant tendency, that it was more important for females to have a contact person available ($F = 3.719$; $p = .055$).

4 CONCLUSIONS

Our results across all academic domains (RQ1) show that female researchers reported about less data sharing and less use of secondary data than male researchers. Furthermore, female researchers are more cautious in relation to the conditions of data sharing and secondary data use. Accordingly, the findings on the higher importance of conditions of secondary data use are analogous to the gender-related differences for the conditions of data sharing, i.e., female researchers agree less to unconditional sharing and favour sharing based on use agreements. This is in line with prior findings [3] that the conditions of data sharing (enablers and barriers) were more important for females. Overall, the results on RQ1 are consistent with previous research on that matter [4] and could lead to the conclusion that – when it comes to data – female researchers are generally more cautious and more protective than their male counterparts.

However, the higher reservations of female researchers can be due to different aspects, internal personal issues as well as external conditions. Thereby, the results on the influence of gender in different domains (RQ2) deliver further insights. The specific results on female and male domains show that the working behaviour must be seen in the light of the prevalent working conditions. In female data-driven domains, females share less often and are less willing to share unconditionally (but more on demand and based on use agreements). Similar, in male data-driven domains with a low visibility of the gender gap, females are less willing to share unconditionally but more on demand. These results for female data-driven domains and male domains with a low visibility of the gender gap are quite similar to the general results (across all domains) on females' reservations in relation to data sharing and secondary data use. However, the pattern of results is completely different for the female domains with a low relevance of data and male domains with a highly visible gender gap: For these domains there were no gender-related differences in data sharing and secondary data use. Even more interesting, in male data-driven domains with a highly visible gender gap, females reported about a higher importance of open access which in turn suggests a (partly) higher openness of females.

Taken these findings together, it seems that the found gender-related differences in data sharing and scientific collaborative behaviour have to be interpreted in a differentiated way. Data sharing is not simply influenced by gender, but rather it depends at least partly on the research domain. Thereby, data sharing behaviour is not simply dependent on the fact if a domain is predominantly male or female. In female data-driven domains we found gender-related reservations towards data sharing whereas for female domains with a low importance of research data there were no gender-related differences. The latter finding seems rather trivial, since a low relevance of research data for the career probably causes less conflicts and gender-related reservations. More interesting is the similar pattern of reservations towards data sharing of female data-driven domains and male data-driven domains with a low visibility of the gender gap. Even though the domains showed a substantial but rather small overweight of male or female researchers, respectively, the gender-related differences are the same. However, for male data-driven domains with a high visibility of the gender gap no gender-related differences were found. Thus, it can be assumed that it is less important if there are more males or more females, but rather the decisional point is how large and visible the gender gap is.

One might argue that a very large and visible overweight of males will put females under social pressure to behave like their male colleagues and thus, gender-differences disappear. However, the findings on publishing behaviour (i.e., females are more inclined to open access in such strongly male-dominated domains) show that females are partly even more open compared to their male colleagues. This contradicts the interpretation that a strong male majority are dominating the behaviour of females.

Another possible interpretation relates to implicit gender stereotypes. Based on prior research reported in the introduction (see especially [16], [17], [18]) it can be assumed that a highly visible gender gap creates a higher awareness of (implicit) gender stereotypes. That means gender stereotypes are made explicit and thus, people have metacognitive insight in the stereotypes and can counteract accordingly. Additionally, due to the highly visible gender gap female researchers receive special attention – that means the attention is directed to women who behave (successfully) in a counter-stereotypical way which in turn can also counteract gender stereotypes [12]. Furthermore, the discussion about females in STEM fields (that are exactly those we identified as male domains with a highly visible gender gap) underlines that the counter-stereotypical beliefs are the social desirable behaviour in male-dominated domains. Such counter-stereotypical beliefs might also influence the "old boy" networks [4]. However, we did not measure the (implicit or explicit) gender stereotypes of our participants and thus, this interpretation on gender stereotypes requires further research.

Another, more simple possible interpretation is related to the pure external circumstances. For male domains with a very large gender gap (high visibility of the gender gap) like the typical STEM-domains, politics provided related support for the careers of female researchers. Thus, the working conditions and career chances for females are more equal (or possibly even better) compared to their male colleagues and thus, the reservations towards data sharing (as possible career obstacles) disappear.

To sum up, our findings provide first evidence on the impact of working conditions (in form of gender-distribution and the importance of research data) on gender-related differences in the collaborative working behaviour of researchers. However, further investigations are needed to clarify the concrete underlying factors (e.g., stereotypes, social pressure, support of females' careers). The knowledge about these underlying processes will enable policies that foster gender equality in all fields of science.

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