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What is Gender Bias in Grant Peer-review?

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ABSTRACT

Competition for research funding on the basis of peer-reviewed grant applications is an essential component of knowledge production. Although women's participation in science is increasing, challenges remain in achieving gender equality in the allocation of research grants. There is a very large literature that attempts to describe and analyze gender bias in academia. However, grant peer review is often researched separately in different disciplines, each applying different criteria and studying different phenomena. The complexity of multi-stage decision making in grant funding mechanisms is largely overlooked in the literature. This study presents a conceptual toolbox to understand gender bias in grant peer review. It explains the key concepts of peer review and the relationships between them, identifies theories of bias applicable to grant peer review, and analyzes their effects in different decision-making contexts.

Keywords: Peer review I Grant Allocation I Research funding I Gender Bias I Implicit bias

INTRODUCTION

Research grants have become a major component of the scientific ecosystem and play a key role in creating new knowledge through funded projects. National and international Research Funding Organizations (RFOs) make substantial resources available in the form of research and career development grants to facilitate academic research. In turn, researchers are increasingly relying on grants to undertake research, and fundraising capacity becomes an important performance indicator for the recruitment and promotion of scholars (Pickett 2019). As a result, considerable efforts have been made to develop selection strategies to fund the best research, as well as to reduce bias in the evaluation of researchers. (The National Academy of Sciences 2007, ERC 2014, CoARA 2022). Nonetheless, studies have consistently shown that gender continues to have an impact on researcher evaluation, particularly when it comes to grant peer review. Women have a lower propensity to access research funds, which can be attributed to gender bias in the grant process (Wenneras and Wold 1997, Bedi et al. 2012).

That said, gender bias in grant peer review remains a controversial topic, as evidence of bias against female applicants is somewhat mixed (Lee et al. 2013). For example, a strand of literature suggests that there is no evidence of specific mechanisms explaining gender differences in grant decisions (Viner et al. 2004, Pohlhaus et al. 2010). This can be explained in part by the fact that research conducted in different disciplines produce sometimes conflicting data and interpretations. Yet, previous literature on gender bias in grant review has focused almost exclusively on the outcome of the review process to explore whether individual-level applications have a comparative disadvantage compared to others (Witteman et al. 2019b). These studies have also been limited in scope, focusing either on specific disciplines or specific institutions. Although they provided empirical evidence, they were limited by a lack of a conceptual basis for analyzing the distinct forms of bias that might occur at different levels of peer review processes. The rationale for this article, therefore, stems from an interest in developing a deeper understanding of gender bias in research evaluation and how it affects grant peer-review and research funding decisions.

In this study, a three-layered analysis is proposed, consisting of i) characteristics of the peer review ecosystem, ii) the hypothesized forms of bias and discrimination, and iii) the operation of grant peer review processes. Each layer focuses on different types of core issues, and together they form a comprehensive characterization of the grant review process, presenting a framework that encompasses all of the key factors of grant peer review that can serve as a foundation for future empirical research on gender bias in grant selection processes.

The paper proceeds as follows. The second section describes the structure of different peer review practices in the research review ecosystem and how they interact. The third section covers the general concepts in the literature on bias and discrimination. The fourth section describes the structure of the grant peer review process and the types of biases that could potentially affect grant funding decisions. The paper concludes with some final remarks.

2. Peer Review Ecosystem

Much of the scientific enterprise focuses on the evaluation of research and researchers, which requires self-regulated experts who practice peer review as a governance mechanism (Chubin and Hackett 1990, Holden et al. 2005). Researchers evaluate the work of others to filter out incorrect or inadequate work and to improve the accuracy and clarity of scientific output. Peer review is recognized as an important component of quality control of knowledge production and have become a recognized tool for identifying the scientific merit of research.

On the other hand, the peer review system has long been criticized for its predictive validity in promoting best scientific practices (Resnik and Elmore 2015), impartiality (Lee et al. 2013) and for its lack of consistent criteria and agreement among reviewers (Hodgson 1997, Cicchetti 2011, Jerrim and de Vries 2020). Some studies show how peers evaluate applications, but little is known about the evaluation criteria used by reviewers (Abdoul et al. 2012, Hug and Aeschbach 2020). Therefore, peer review may also include biases that are unlikely to be based on meritocratic principles, which, in turn, can have a significant impact on the outcome of the review process.

Peer review is applied to a number of research evaluation processes, the selection of conference applications, the publication of journal articles, the evaluation of research grant applications, and the hiring process when scientists are evaluated for a new position or promotion. These areas are also the most common places where discriminatory practices against women can be very evident. Indeed, the effect of gender in peer review of grant applications as well as in peer review of scientific journals and in academic recruitment has been documented in the literature (Long et al. 1993, Lariviere et al. 2013). The practices and outcomes of all of these compartments of the research evaluation ecosystem are important in their own right, but they are also interrelated. Each of these outcomes can lead to other events influencing the peer review decision-making processes. For example, research careers, grant success, and access to academic networks are often intimately linked to researchers' bibliometric indicators (Leahey 2007, Laurance et al. 2013). Academic affiliation and networks can be both the cause and result of academic success. (Ebadi and Schiffauerova 2015, Leberman et al. 2016). The same is true for the relationship between grant

award rates and research careers (Bloch et al. 2014). Therefore, a biased decision can have a significant direct or indirect influence on the outcome of other decisions in the peer review ecosystem.

However, while they share the same ecosystem, the process and reasoning behind the decisions, and practical implications for grant funding, publication, and hiring differ depending on the review context. Theoretical engagement in research on peer review (Hug 2022) and identifying fundamental differences in peer review processes would thus provide a basis for examining the implications of gender bias in grant peer review.

This section is structured around an analysis of the function, history, and scope of peer review as a major component of research evaluation in (i) faculty hiring, (ii) manuscript review, and (iii) grant funding.

2.1. Faculty recruitment. Building on the classic work of Merton (1973), extant research has established ample, but fragmented, evidence of gender differences in science careers. Studies have explored an apparent gender gap in graduation and career transition rates (Laudel and Glaser 2007, Lerchenmueller and Sorenson 2018), promotion rates (Lundberg and Stearns 2019), salary (Ginter and Hayes 2003), and career persistence (Ledin et al. 2007). Yet, there is already a large literature on the effects of gender on the faculty hiring process (Williams and Ceci 2015, Eaton et al. 2020).

Several mechanisms may explain the lack of women in certain academic positions. The metaphor of the 'leaky pipeline' is frequently used to describe this fact; a pipeline that carries researchers from pre-university to tenure track. This pipeline leaks researchers at various stages in which women leak out more than men do, therefore creating a gender-based filter that keeps women out of the academic career stream, resulting in gender imbalance in academia (Blickenstaff 2005). Indeed, the proportion of women faculty members remains low, even though the recruitment rate of women at the undergraduate and doctoral levels has improved over the decades (Ginther and Kahn 2004). Recently, Huang et al. 2020 argued that the university system loses women at every stage of research careers and that the cumulative impact across the career significantly increases the gender disparity for senior academics. This is particularly evident for female academics working in STEM (Howe-Walsh and Turnbull 2016), even though there is a positive relationship between gender diversity and departmental rankings in STEM disciplines at research universities (Henderson et al. 2017).

Many possible explanations have been considered for this leakage, including the existence of gendered roles at the individual level (Kulis et al. 2002), family formation and household

responsibility for women (Monosson 2008), disruptions in women's self-promotion (Moss-Racusin and Rudman 2010), lack of female role models (McGuire et al. 2021) and support networks of mentors and peers (Blau et al. 2010, O'Meara and Stromquist 2015). Some studies indicate the role of research networks and gatekeepers in hiring decisions (van den Brink and Benschop 2013, Zinovyeva and Bagues 2015, Bagues et al. 2017). In addition, another line of research has shown that women are less likely to apply for promotions (De Paola et al. 2017), perhaps due to gendered preferences in competitive environments (Niederle and Vesterlund 2007, Buser et al. 2014) or labor market negotiation skills (Bowles et al. 2007). For example, Mairesse and Pezzoni 2015 analyzed gender differences in scientific productivity and promotions for two large samples of French physicists from CNRS and universities and found that women are less likely than men to be promoted to a higher rank, regardless of the number of publications, suggesting that there may be gender differences in non-research activities and commitments.

That said, there are some structural differences between faculty hiring processes and other types of peer review practices, particularly in terms of the requirements and qualities that candidates must possess. Different faculties may have different requirements and reasons for hiring depending on research focus and administrative needs. Some faculties are not designed for research, so some positions may not require strong research training or scientific excellence, but strong teaching skills and administrative experience.

However, while tenure standards and expectations may vary across faculty, the literature shows that the lack of transparent criteria in selections can lead to discrimination in faculty hiring (Ledwith and Manfredi 2000, Ziegler 2001). Although the use of bibliometric measures in assessing the performance of individual researchers has increased significantly, they can contribute to perpetuating existing gender inequalities in academia (Nielsen 2018). A recent study (Weisshaar 2017) of a sample of assistant professors in sociology, computer science, and English at research universities found that productivity measures explain only a portion of gender disparities in tenure, and that much of the gender gap in faculty hiring remains unexplained by these factors. Yet, although departmental characteristics have no effect on the gender gap in tenure, female faculty are on average tenured in less prestigious departments than men.

Overall, a number of factors such as the structure of academic networks, faculty and university human resource priorities, and characteristics of applicants other than their research background may directly affect hiring decisions. Therefore, gender differences in science careers could be explained by multiple and intersecting forms of structural discrimination in hiring mechanisms.

2.2. Manuscript review. Communication and exchange of research results through publication are the most fundamental social processes of science (Fox 1983). Research productivity remains one of the primary means by which researchers are judged for their scientific merit. And the most critical indicator of research productivity for researchers is considered to be the publication record because it can be easily evaluated and recognized by the scientific community (Gustin 1973).

Gender differences in scientific productivity have been widely explored in recent years, and the study of authorship and bibliometrics from a gender perspective -often referred to as the *productivity puzzle* (Cole and Zuckerman 1984, Xie and Shauman 1998)- has received increased attention (Mauleón et al. 2013, Ceci et al. 2014). There is a general consensus in the research literature that the measured productivity of female faculty is lower than that of male faculty, albeit to a decreasing extent over time, in most disciplines (Abramo et al. 2009), and the differences are even more pronounced among senior scientists (Aguinis et al. 2018). However, in some studies, no gender differences were found in terms of citations per publication measure (Tower et al. 2011). These results imply that women's lower publication rates lead to lower total citations. On the other hand, Nygaard et al. 2022 argued that the way an indicator is constructed can affect the perception of gender differences in productivity. Productivity indicators may have a small but cumulative effect that results in women receiving fewer points than men per publication.

There are several explanations for the *productivity puzzle*: it has been attributed to factors such as self-selection, career preferences or social selection, and accumulated disadvantage or the Matthew/Mathilda effect (Merton 1968, Rossiter 1993). For example, women scientists may self-select into the competition of scientific production due to career interruptions and work/family imbalance (Prozesky 2008). Having children explains differences in gender productivity rates over time. For example, Stack (2004) found that although parenting is not a significant predictor of productivity, and its influence follows a gendered pattern. Individual scientific productivity growth declines after the birth of a child, but even more so for female scientists (Hunter and Leahey 2010).

Given that journal peer review is an essential part of scientific production, a significant portion of the research on gender differences in bibliometric indicators has long been a major focus of the study of scientometrics. However, the reliability of peer review of scientific articles and the evaluation criteria used by reviewers to rank submitted articles are critically examined in the literature (Allen et al. 2009, Bornman 2012). In an attempt to study methods of evaluating the merit of a scientific article, Eyre-Walker and Stoletzki (2013) found that in post-publication evaluations, reviewers tend to overvalue articles published in journals with a high impact factor. They also found a weak correlation between post-publication evaluation scores and citation counts, suggesting that

reviewers fail to judge the scientific merit of an article and its potential impact. They found that relying solely on bibliometric indicators would have missed articles containing important results. These findings inevitably raise doubts about the impact of author gender on journal peer review processes. Indeed, a stream of literature, following the seminal works of Goldberg (1968) and Paludi and Bauer (1983), has shown evidence of gender differences in referee evaluations, where submissions written by women are evaluated more critically (Krawczyk and Smyk 2016) -though there are exceptions (Borsuk et al. 2009). Accordingly, in an experiment (Blank 1991) on blind review practices in scholarly journals, acceptance rates for submissions written by men are found to be significantly higher in unblinded samples, indicating that male authors have a comparative advantage when their names (and gender) are revealed. Knobloch-Westerwick et al. (2013) also conducted an experiment with 243 young communication scholars in which participants evaluated conference abstracts and found that perceived scientific quality was higher for publications written by men. Consistent with these findings, previous research has shown that the peer review process for articles written by women takes significantly longer (Hengel 2007).

The gender composition of editorial boards can also have varying effects on the peer review of journals. Researchers may enjoy increased visibility and prestige as an editor or member of an editorial board, which may influence grant awards, employment, and promotions. Holding a position on a journal's editorial board is considered evidence of a high reputation within the scientific community. Yet, obtaining such positions can serve to strengthen the academic network of researchers. Some studies have examined women's participation on scholarly journal editorial boards and reported a gender gap in position characteristics (Metz and Harzing 2009, Stegmaier et al. 2011, Amrein et al. 2011, Cho et al. 2014, Lerback and Hanson 2017). For example, Addis and Villa (2003) compare the presence of male and female economists on the editorial boards of 36 Italian economic journals published since 1970, and conclude that the presence of women in senior academic positions does not correlate with their presence on the editorial boards of economic journals. This is particularly important because gendered differences on the development of network ties may lead to distinct patterns of editorial decisions in the selection of reviewers. Helmer et al. 2017, using a dataset of 9,000 editors and 43,000 reviewers from the Frontiers journal series, showed that editors of both genders appear to prefer working with reviewers of the same gender. Such preferences could in turn affect the outcome of reviews and final selection (Lane and Linden 2009, Wing et al. 2010) although, as Bransch and Kvasnicka 2017 suggest, the publication process may not be governed exclusively by gender bias and could not be easily rectified by gender-mixed policies in editorial boards.

Overall, although editors and reviewers are interdependent and unbiased actors in the publishing mechanism, they may have a somewhat biased position. A number of factors can influence the decision-making process, such as the author's gender and affiliation, citation expectations, and managerial priorities. Their decisions, whatever they may be, have an indirect but significant impact on researchers' academic careers, and their ability to secure research grants.

2.3. Grant funding. Competitive research funding affects the dynamics of the research ecosystem. For example, academic career development today represents a sustained commitment to research that has the potential to attract research funds (Lee and Bozeman 2005). The ability to raise funds is becoming a key measure in evaluating researchers' performance, along with the publication record. Research grants also facilitate academic collaborations, creating linkages within academic circles and potentially enhancing the status and recognition of the grant recipient. (Katz and Hicks 1997). However, funding for scientific research has become more difficult to obtain, especially for female researchers. The inability to lead research projects prevents women from gaining the experience needed to advance their academic careers and has a disproportionate impact on the number of women faculty in leadership positions, as *women who obtain funding remain in the workforce* (Hechtman et al. 2018). There may be a direct relationship between research grants and research outcomes, but grants also have an indirect impact on the researchers themselves. For example, Bloch et al. 2014 find that receiving grants leads to a significant increase in the likelihood of being promoted and moving into a full professor position. Their results indicate that the probability of becoming a full professor is nearly doubled for grant recipients.

Previous studies show that gender bias may contribute to the outcomes of peer review processes. For example, there is strong evidence of bias in research grant peer review that is 'of sufficient magnitude to change the scores of applications for funding or non-funding' (Tamblyn et al. 2018), and the factors underlying the gender gap in grant awards may reflect less favorable evaluations of women as principal investigators, but not of the quality of their proposed research (Witteman et al. 2019a). Thus, understanding potential sources of bias in grant selection processes may be particularly important to mitigate this gender gap. In an attempt to explain this phenomenon, a large body of research has been documented. A set of common findings, as well as information about the datasets (countries and RFOs) traversed by this literature can be seen in **Table 1**.

Table 1: Previous empirical studies on gender bias in grant peer-review

Reference	Country	RFO	Period	Discipline	Dependent Variable	Gender Effect
Banal-Estañol et al. (2019)	UK	EPSRC	1991-2007	Engineering and Physical Sciences	Awarded or not	No
Bautista-Puig et al. (2019)	EU	ERC	2007-2016	All Disciplines	Awarded or not	Yes
Bedi et al. (2012)	UK	Wellcome Trust	2000-2008	Biomedical Sciences	Awarded or not	Yes
Bol et al. (2022)	Netherlands	NWO	2005-2016	All Disciplines	Scores+ Evaluation stages	Yes
Burns et al. (2019)	Canada	CIHR	2000-2014	Biomedical Sciences	Awarded or not	Yes
Cañibano et al. (2009)	Spain	Ramón y Cajal Programme	2005-2006	Physics, Molecular Biology, Philosophy and Philology	Awarded or not	No
Ginther et al. (2011)	USA	NIH	2000-2006	Biomedical Sciences	Awarded or not	Yes
Ginther et al. (2016)	USA	NIH	2000-2006	Biomedical Sciences	Awarded or not	Yes
Head et al. (2013)	UK	Various	1997-2010	Biomedical Sciences	Awarded or not	Yes
Jagsi et al. (2009)	USA	NIH	1993-2007	Biomedical Sciences	Awarded or not	Yes
Lerchenmueller and Sorenson (2018)	USA	NIH	1985-2015	Biomedical Sciences	Awarded or not	Yes
Magua et al. (2017)	USA	NIH	2010-2014	Biomedical Sciences	Scores+Sentiment analysis	Yes
Mutz et al. (2012)	Austria	ASF	1999-2009	All Disciplines	Scores+Awarded or not	Small
Polhaus et al. (2011)	USA	NIH	1999-2004	Biomedical Sciences	Awarded or not	Mixed Results
Sandström and Hällsten (2008)	Sweden	VR	2004	Biomedical Sciences	Scores	No
Severin et al. (2020)	Switzerland	SNSF	2009-2016	All Disciplines	Scores	Yes
Tamblyn et al. (2018)	Canada	CIHR	2001-2005	Biomedical Sciences	Awarded or not	Yes
van der Lee and Ellemers (2015)	Netherlands	NWO	2010-2012	All Disciplines	Scores+Sentiment analysis +Evaluation stages	Yes
Witteman et al. (2019)	Canada	CIHR	2011-2016	Biomedical Sciences	Awarded or not	Yes
Yip et al. (2020)	Hong Kong	Uni. of Hong Kong	2015-2020	Social Sciences	Awarded or not	No
Bianchini et al. (2022)	EU	ESF	2003-2010	All Disciplines	Scores+Sentiment analysis+Awarded or not	Yes

Notes: Gender bias in research funding has been studied by different research areas, across disciplines and countries for more than three decades. See, e.g., Bornmann et al. (2007) and Marsh et al. (2009) for a systematic review and meta-analysis based on the literature published before 2007. The studies mentioned in this table start from 2008. Only a few studies examine the review materials and each step of the grant evaluation process.

Overall, decisions made in the peer review ecosystem can be driven in part by biased perceptions rather than the qualifications and merit of the researcher. However, the predominant form of bias may change as a result of changes in selection mechanisms. Therefore, distinct theoretical approaches to the extent to which female researchers face discriminatory practices could explain the bias. Key concepts of gender bias and how they relate to peer review of grants are discussed in more detail in the sections below.

3. Identifying Gender Bias

The study of attitudes, stereotypes, biases, prejudices, and discrimination has received considerable scholarly attention since Gordon Allport's seminal work, *The Nature of Prejudice* (1954), in which he presented a comprehensive systematization and review of the literature on the societal, group, and personality determinants of prejudice acquisition.

Cognitive biases refer to representations produced by human cognition that are systematically distorted (Haselton et al. 2015) or deviated (Cosmides and Tooby 1994) from rational behavior or

state of nature. A bias is considered sub-optimal decision making based on systematic simplifications and deviations from principles of rationality (Korteling et al. 2018). Biases in judgments can reveal certain heuristics of thinking under uncertainty (Tversky and Kahneman 1974). As a result, we may use intuitive strategies and heuristics that may be partially effective but likely to produce biases that lead to systematic errors (Shafir and LeBoeuf 2002). Cognitive biases may be widespread, persistent, and systematic. And similar heuristics can be used under a wide range of different conditions (Kahneman 2011). Gender bias is therefore associated with processing inaccurate perceptions of gender-stereotyped information that may not be justified by any particular merit or reciprocity, but by being a woman as a member of the target category.

The discussion of gender bias in academia in the relevant literature occupies a great deal of space without having resulted in precisely agreed upon definitions. This is partly because the study of gender is still a developing field of inquiry in the social sciences, and much has changed in the presumed factors explaining gender differences since the early 20th century (Risman and Davis 2013). There is little overall explanation for the phenomenon; rather, theories continue to be developed alongside developments in other relevant theories. Connell (1985: 261) argues that this is because 'social gender theory is not a tightly bound logical system. Rather, it is a network of intuitions and arguments about connections.'

Researchers have pointed to a multitude of factors to explain gender bias, including but not limited to stereotypical beliefs and gender profiling (Reuban et al. 2014, Leslie et al. 2015, Bordalo et al. 2019). In her seminal work, Keller (1978) made an interdisciplinary contribution to the critique of gender and science, referring to 'the historically pervasive association between the masculine and the objective, and more specifically between masculine and scientific' (Keller 1978: 81). She argues that masculinity persists not only in the persons of scientists, but also in the substance and *ethos of science* (Schiebinger 1999). The *masculinity of science* thus emerges as one of the key concepts for studying gender bias in academia, particularly in grant peer review.

3.1 Stereotypical beliefs and gender profiling. Stereotypes are generalizations about groups that are applied to individual group members simply because they belong to that group (Heilman 2012). Stereotypical judgments are typically based on erroneous inferences about the relationship between categories of events, i.e., an overestimation of a particular type of behavior allegedly engaged in by members of a particular group (Hamilton and Gifford 1976). Accordingly, gender stereotypes are generalized views or preconceptions about the attributes of men and women.

Gender remains one of the strongest social foundations on which we base our stereotypes (Wood and Eagly 2010), and gender categorization is an important aspect in the development of social relationships (Fiske and Stevens 1993, Diekman and Eagly 2000). According to Acker (1973), ‘...the sex dichotomy cuts across all classes and strata (This is also true of ethnicity and race.)’ (p.940). Studies have shown that we unconsciously and automatically categorize the gender of any person with whom we relate (Ford and Stangor 1992, Blair and Banaji 1996). Male/female identification is typically the first practice people make to sort the self and the other in social interaction, and subsequent categorizations along other social dimensions such as age or occupation are built on the initial understanding of gender differences (Brewer and Lui 1989, Liberman 2017).

Ridgeway and Correll (2004) have shown that in some contexts where gender is not necessarily a primary category in person identification or a particularly strong determinant of behavior, gender still functions as a foundational principle for organizing social relationships; perhaps because it is a simple and straightforward classification unlike other classifications. Yet, while the impact of gender stereotypical beliefs may be negligible in a particular case, their effects accumulate over the life course and result in significantly different life courses and social outcomes for men and women (Ridgeway and Correll 2004).

Stereotypical beliefs about gender-specific traits, roles, and occupations have remained very stable over the past few decades (Haines et al. 2016, Rolin and Vainio 2011), although some studies show changes in favor of women over time (Eagly et al. 2020). Women are generally accorded less status and skills than men (Fiske et al. 2002). Leadership is also constructed as a male trait (Madera et al. 2009). Swim and Sanna (1996) show that when men have been successful in a culturally defined masculine domain, their success is attributed to innate ability and talent, while women's success in the same domains is attributed to external factors. Words associated with intelligence and competence are part of the group of positive traits considered typical of men, not the group of positive traits considered typical of women (Carli et al. 2016, Bian et al. 2017).

The evaluative bias in favor of men is stronger in tasks labeled as masculine (Eagly and Karau 2002), supporting the hypothesis that science is a masculine social construct. Indeed, studies show that women are portrayed as less capable or competent in terms of scientific merit, even when their overall performance is not significantly different (Moss-Racusin et al. 2012). Men still more likely than women to be perceived as academic leaders (Ellemers et al. 2012). These stereotypical gender attributions can negatively impact peer evaluation of female researchers' scientific merits and successes by systematically undervaluing their skills relative to their male counterparts.

3.3. Implicit and explicit bias. A stream of studies has focused on understanding biases resulting from conscious and unconscious operations (Greenwald and Banaji 1995, Olson and Fazio 2009), suggesting that the decision-making process can take place both consciously and unconsciously, or occurs above and below the surface of consciousness (Loftus and Klinger 1992, Devine 1989). In this sense, the expression of discrimination and prejudice can be classified into two categories: conscious or explicit, and unconscious or implicit.

With respect to *explicit bias*, we can classify two main theories of discrimination where much of the debate about the underlying causes of discrimination focuses on the rationality of individual decision making. The first theory is based on intentional preferences and called *taste-based discrimination* (Becker 1971). In the taste-based theory, discrimination is based on the presence of prejudice; individuals prefer not to interact with a particular group of people. In this model, individuals have a *taste for discrimination*, which means that there is a degree of dislike for particular profiles. For example, in the taste base scenario, suppose an evaluator does not want to treat female researchers equally, even if they are as productive as others. In a context where the reviewer needs to identify and qualify the best research proposals (using scientific merit as a metric), he or she would give the same scores to all submissions of similar qualities, but simply not give the same scores to female researchers if he or she is biased. In this case, to be judged equally, female researchers would actually have to perform better than male researchers. Thus, if it is possible to obtain better scientific results from the proposals of female researchers than from those of men, i.e., by treating female researchers as equal to their lower-ranking male counterparts when this is not warranted, by awarding fewer grants, or by expecting greater impact than male researchers, then the evaluator faces a trade-off: he or she can award the same scores to female researchers and thereby increase the quality of the overall research results. Or he or she can discriminate and give lower scores to female researchers, even if this results in a lower quality of overall research output. In the latter case, then, discrimination imposes a cost on the integrity of science and scientific merit.

The other main explanation is called *statistical discrimination* and is based on incomplete information. The simplest information-based model implies that one group has mistaken beliefs about the skill level of another group and acts accordingly (Levitt 2004). In this case, bias is the result of trying to manage uncertainty. Although stereotyping can be *inaccurate* (see Fiske 1998) and does not necessarily reflect objective assessment measures (Bohren et al. 2019), it can lead to extensive use of readily observable characteristics such as race or gender to infer an individual's expected outcome. For example, if the evaluator believes that female researchers expect to drop out

of research activity due to stereotypical gender-related qualities such as family responsibilities, etc., and therefore are less likely to have long research experience and scientific impact than their male counterparts, there should be an observable difference in evaluation models. The more complete the candidate information, the more weight the reviewer places on that information; the less informative the signal, the more weight the reviewer places on the average scientific productivity of female researchers. If the reviewer lacks specific information about the candidate's merit indicators, the reviewer's optimal prediction of scientific potential would be a weighted average of the candidate-specific signal the reviewer receives and the average patterns of scientific productivity among female researchers, for which there is ample evidence of differences in favor of men.

On the other hand, *unconscious* or *implicit bias* refers to the bias that operates outside of the person's awareness. *Implicit bias* is not necessarily perpetrated by an intentional act unlike statistical discrimination. That said, there is a growing body of theoretical and empirical research on implicit bias, albeit with what are, at times, divergent interpretations of the 'implicit' construct (Corneille and Hutter 2020). For instance, the well-known measure of implicit attitudes – the Implicit Association Test (IAT) (Greenwald et al. 1998)– has recently been criticized because of serious limitations in the evidence base for implicit malleability and change (Forscher et al. 2019) and, more generally, for its predictive validity (Oswald et al. 2013).

Here, this study adheres to the conjecture in the implicit bias literature (Mandelbaum 2015, Frankish 2016) that individuals are implicitly biased if their behavior manifests a stereotypical conception, even if they do not explicitly endorse that conception and often reject it.

4. How the grant peer review process works

The grant peer review process involves different reviewers with different decision-making structures. Grants typically come from national and international research funding organizations (RFOs) such as the European Research Council (ERC), National Institute of Health (NIH), National Science Foundation (NSF), French National Research Agency (ANR), German Research Foundation (DFG). Although RFOs may develop and implement different criteria and procedures for evaluating and selecting funding proposals (Chubin 1994, Geuna and Martin 2003), most rely on external peer review and expert panels to determine successful applicants.

The grant peer-review typically includes at least two steps: i) evaluation by a review committee, with the possibility of several meetings at different stages; ii) evaluation by external experts. Final decisions are made by the RFOs, where the reviewers' scores and the committee's discussions play a fundamental role in the acceptance or rejection of grant applications. The review process includes

the following steps. Once applicants have submitted their applications, project proposals are checked for eligibility and suitability to identify whether they meet the conditions of the call or other rules prescribed by the funding institution. In some cases, this step is carried out by panels of experts (ESF, ANR, etc.). Then, external reviewers are invited to evaluate the proposals. The number of external reviewers depends on various factors such as the amount of grant available, the objectives and the funding framework of the call. In the external review process, proposals are scored according to the evaluation criteria of the funding institution. At the end of the external review process, an independent panel of experts evaluates each project proposal in light of the review reports, scores, and scientific merit of the applicant and decides whether to recommend funding. The funding institution itself makes the final decisions.

The grant peer review mechanism itself, particularly the sequential steps and different actors in the selection process, has been little studied. Thus, we know relatively little about the extent and complexity of the social and scientific interactions among actors, as well as the implications of gender bias in the grant peer review process. Yet the multi-stage nature of grant peer review has been largely overlooked in previous research, where the vast majority of studies on grant peer review focus on ex-post and ex-ante impact analysis and predictors of proposal success and failure, with a number of experiments conducted on relatively small data sets. There are few studies analyzing the review documents, as well as the different stages of the grant selection process. **Table 2** summarizes three of the cutting-edge approaches -Mutz et al. 2012, van der Lee and Ellemers 2015 and Bianchini et al. 2022- to gender bias analysis in grant peer-review and shows the variables used in these studies. These studies rely exclusively on peer review data in the form of scores and texts, and results from both review panel/committee and external reviewer assessments.

Among three studies, Mutz et al. 2012 and van der Lee and Ellemers 2015 provide compelling evidence of the links between candidate and evaluator characteristics, and the selection of successful proposals. The latter study also included a content analysis of language use in instructional and assessment materials, as well as an analysis of assessments and success rates. However, van der Lee and Ellemers (2015) study is criticized for inappropriate statistical procedure, and is therefore found questionable, due to the so-called “Simpson’s paradox” (Albers 2015, Volker and Steenbeek 2015). As for the studies by Mutz et al. 2012 and 2014, they are limited to national funding programs (FWF) and individual grant applications, ignoring trends in multinational and multidisciplinary research. Yet, while both of these studies used very rich data on the evaluation processes, they did not include in their analysis the characteristics of the panel and external reviewers, nor the network relationships with the candidates, due to data limitations. However, they

recommend further empirical studies on the links between peer reviews, funding decisions, and other objective criteria for project success, such as bibliometric data.

Table 2: Variables used in previous studies

	Mutz et al. 2012	van der Lee and Ellemers 2015	Bianchini et al. 2022
<i>Dependent Variables [Evaluation stages]</i>			
Review committee/Panel decisions	YES	YES	YES
External reviews/Reviewer scores	YES	YES	YES
Interviews	NO	YES	NO
Final decision	YES	YES	YES
Sentimental analysis of review reports	NO	NO	YES
Gendered language in instructional and evaluation materials	NO	YES	NO
<i>Independent Variables [Applicants]</i>			
Gender	YES	YES	YES
Age	YES	NO	YES
Affiliation	NO	NO	YES
Experience level	NO	NO	YES
Discipline	YES	YES	NO
Productivity	NO	NO	YES
Citations received	NO	NO	YES
Private Partnership	NO	NO	YES
Past Grant Application	NO	YES	YES
Budget Requested	NO	NO	YES
Network Proximity	NO	NO	YES
Cognitive Proximity	NO	NO	YES
Research Diversity	NO	NO	YES
<i>Independent Variables [Evaluators]</i>			
Gender	YES	NO	YES
Age	NO	NO	YES
Affiliation	NO	NO	YES
Experience level	NO	NO	YES
Discipline	YES	YES	NO
Productivity	NO	NO	YES
Citations received	NO	NO	YES
Private Partnership	NO	NO	YES
Network Proximity	NO	NO	YES
Cognitive Proximity	NO	NO	YES
Research Diversity	NO	NO	YES
Review committee/Panel size	NO	NO	YES
Review committee/Panel workload	NO	NO	YES

Notes: These three publications are selected on the basis of their analyzed data. Only works based on data collected through peer review processes are considered. There may be different variables in other works that are not included in this list.

Bianchini et al. 2022, on the other hand, described one of the most comprehensive primary studies of the effects of gender in peer review of grant proposals, based on data from EUROCORES program in which multinational collaborative research in multiple scientific fields was promoted between 2003-2015 and involved international consortia (9,158 principal investigators) evaluated sequentially by 485 expert panel members and 2,182 external reviewers. The study is comprehensive because of its size but also because it includes demographic and bibliometric information on applicants, panel members, and reviewers; it includes panel decisions, peer review scores, and texts from all disciplines; and it analyzes the association between the proportion of female PIs in EUROCORES research consortia and the decisions made by individual reviewers throughout the three stages of the review process.

Bianchini et al. 2022 found significant gender effects at different stages of the evaluation process. Consortia with a higher ratio of female principal investigators were significantly less successful in

the first selection of the evaluation panel, and received lower scores from external evaluators. Applying advanced NLP and text analysis techniques (VADER, SentimentR, Word2vec, etc.), they also found a discrepancy between the scores and the written evaluation of the review reports. They conclude about differences in the decision-making mechanisms of expert panels and external reviewers and suggest that these differences may be responsible for distinct forms of gender bias at different stages of evaluation.

The following sections draw primarily on the results of the aforementioned studies and link existing theories and models of discrimination to the discussion of gender bias in grant peer review that, to date, have remained controversial.

Expert Panels. In a typical peer review process, panels and external reviews are two main parts of a sequential decision-making mechanism. However, panel decisions, as group decisions, may involve additional factors that are not necessarily accounted for by theories that focus on a single decision maker (Sassenberg et al. 2014, Daskalova 2018). The panel's decision is an important component of the larger peer review process (Sorrell et al. 2018) because the funding decision is found to be best predicted by the panel's score.

Panel members review significantly more grant applications in a short period of time. And the panel, in most cases, is responsible for selecting those projects that appear to have better value than others and that can be subject to external review. Although there are exceptions in the selection process of different RFOs, the initial grant applications include only abstract or a summary of the full proposal. Panel members thus process less detailed information about applicants and relatively large number of proposals when making their selection decisions (van Arensbergen et al. 2014). Because of the lack of time to adequately review each project and each characteristic of the applicants, panel members may be more inclined to adopt a decision-making strategy based on group characteristics. However, while the heuristics employed by panel members may speed up the decision-making process, they may introduce errors and lead to gender bias on the part of the panel.

For example, Bianchini et al. (2022) found that scientific output (represented by the number of previous publications) did not significantly influence the panel's decisions. Instead, panel members appear to use gender-specific traits to predict academic ability at the time of selection. Future research could usefully investigate these complex and dynamic decision making process. Consider, for example, that because of stereotypical gender beliefs (masculinity of science), signals associated with leadership skills and ability to accomplish a scientific project should be noisier for women than for men. Then, as statistical discrimination theory suggests, a 'quality-maximizing' panel would

make less favorable evaluations of principal investigators in the demographic group with the noisiest signal. In this sense, lack of information may lead panels to treat female researchers based on stereotypical gender qualities. If this is the case, future research could usefully study these complex and dynamic decision-making processes on the basis of statistical discrimination theory.

External reviewers. In contrast to the expert panel's decision-making process, external reviewers have access to all necessary information about the proposed research and applicants (full proposal), and they typically review a project in their area of expertise over a relatively long period of time. In most cases, reviewers are provided with review guidelines and step-by-step instructions on how to score applications and formulate their written critiques. That said, there is little agreement on how to perceive and translate the level of application quality in the text of reviews and scoring (Pier et al. 2018).

A growing number of studies suggest text mining algorithms to discover implicit patterns in reviewers' critiques (Magua et al. 2017, Kolev et al. 2020, Stappen et al. 2020). However, only a few research studies have been conducted to understand the differences between review texts and review notes. For example, Bianchini et al. 2022 estimated the polarity of sentiment and the rate of emotion at the sentence level to capture whether the review text expresses a positive, negative, or neutral sentiment of the reviewer about the research team and the proposed research in question. Their results show that the valence scores of the review texts are not affected, either positively or negatively, by the gender composition of the applicant teams, but that the evaluation scores are. External reviewers did not perceive female applicants as less qualified in their commentary, but they were negatively sensitive to the female ratio when rating the proposed research. This may imply that implicit associations may have contributed to these results.

Although more research is needed to determine the types of biases that may be involved in external reviewers' decision making, textual analysis of review reports provides an additional layer of examination of implicit biases in grant peer-review. For example, as Frankish 2016 suggests, an individual is implicitly biased if their behavior manifests a stereotypical view, even if they do not explicitly subscribe to that view and perhaps explicitly reject it. Following this line of reasoning, the reviewers may have thoughts and feelings that they do not report verbally and that are largely beyond their awareness and control, but that are manifested in the evaluation scores. This approach could provide researchers with a conceptual tool along with the IAT and the Perceived Subtle Gender Bias Index (PSGB Index) (Tran et al. 2019) to identify implicit associations in external reviewers' decision-making.

CONCLUSION

Evidence from previous studies suggests that gender bias can affect the outcome of peer review processes. Understanding the sources of potential bias is therefore essential to mitigate the gender effect. This paper presents an approach to the study of gender bias in grant peer review that contributes to the understanding of the complex, multi-stakeholder and multi-stage decision-making processes of grant peer review. This study is the result of a review of existing knowledge, focusing not only on empirical research, but also on studies from different fields, to deepen understanding of grant peer review, with the aim of linking conceptual elements of gender bias to empirical studies of research evaluation. The study also provides a conceptual basis that can serve as a foundation for future research on gender bias in grant selection processes.

A few conclusions can be drawn from this study. First, there are distinct fundamental mechanisms shaping the peer review process: the expert panels and external reviewers who respectively assess grant applications throughout the selection process. Each decision-making process presents challenges to which peers and stakeholders need to pay particular attention in order to improve the quality of the review and reduce the impact of gender bias. It is therefore important to examine how decision-making practices differ during peer review activities at these selection stages, and how these different practices can be influenced by various types of bias. A set of core concepts such as stereotypical beliefs, gender profiling and implicit and explicit bias are particularly relevant to addressing the effect of gender on evaluation decisions in the later stages of grant peer review.

Second, gender bias affects all forms of peer review and can be very specific depending on context, time, place and discipline. To address these sources of heterogeneity, this study proposes a three-layered framework: i) the categorization of existing review procedures in the peer review ecosystem, with different practical implications for different peer review practices; ii) the analysis of the theoretical background that could explain bias in grant peer review; iii) the functioning of the grant peer review process, in which the procedure and rationale for decisions can vary in ways that affect the form of bias that can occur.

Third, biases are not always conscious, obvious or easily detectable, but can be systematic and structural. Gender bias must therefore be seen as a broader social, structural and political challenge. Effective engagement of the research community could address the root causes of the attrition of women scientists from senior research positions and the disproportionate success rates of women among grant recipients.

Finally, gender bias research relies on pre-existing data sources generated by RFOs. A considerable amount of data generated by RFOs from various grant calls has not been made available to researchers. Rich data sources in the form of texts and notes at all stages of the evaluation process are essential for effective research on gender bias in peer review of grants. Efforts to improve gender equality in academia are important, but will have limited impact if it is not possible to measure the processes by which bias plays a role in funding decisions. Sharing research evaluation data and making it available to a wider scientific community would be the crucial first step in opening up new avenues of research, with great potential for mitigating bias in the peer review ecosystem.

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