Female expertise in public discourses. Visibility of female compared to male scientific experts in German media coverage of eight science related issues

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Abstract

A fair (public) representation of women is one of the most discussed questions of our time. The way in which media coverage (re)produces genders may affect individual and collective thinking and the assessment and perceptions of women in society. We analyse the representation of female scientists in German news media coverage about eight science-related risk issues and compare male and female experts regarding their relative scientific reputation, the number of references and the content of their statements. Our findings show that female scientific experts play a subordinate role in German media coverage and that they are underrepresented compared to the respective proportions in the relevant research areas. At the same time, our data relativize the extent of the gender visibility gap, as the differences – after controlling for hierarchical position and scientific reputation – become rather small. Further, we find no evidence of discrimination against female scientific experts through journalistic selection routines.

Key Words

gender; diversity; gender visibility gap; media coverage; content analysis; science communication; risk communication

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Introduction and research questions

A fair representation of women, for example in media coverage, is referred to as one of the most discussed questions of our time (Trepte and Loths, 2020) and as a challenge for journalism. This is because an under-representation of women in media coverage could lead to potential harmful effects for society as a whole, which are discussed scientifically. From the point of view of deliberative theories of democracy and of the public (e.g. Habermas, 1992), it seems normatively desirable and relevant that representatives of all social groups can participate in public discourse. Who is not represented in media coverage will hardly be heard by the general public. Beyond that, cultivation theory suggests that media coverage may affect the idea of social reality in the audience (Gerbner and Gross, 1976), for example notions of who is meaningful or relevant for society and who is not (Fryberg and Townsend, 2008). An "underrepresentation in the media affects the 'unseen' themselves as well as how they are viewed by society as a whole." (Jürgens et al., 2022: 175) In sum, the way in which media coverage (re)produces genders affects individual and collective thinking and the assessment and perceptions of women in society (GMMP, 2020; Magin and Stark, 2010).

This is also true for women in science, where there are gender differences in the visibility of scientists (so-called 'Gender Visibility Gap', Klammer and Wegrzyn, 2023). Studies show that these gender differences exist on two levels of visibility: within science, e.g. in publications and citations (e.g. Chatterjee and Werner, 2021; Huang et al., 2020; van den Besselaar and Sandström, 2017), and in science communication (e.g. Eizmendi-Iraola et al., 2023; Fletcher et al., 2021; Prommer and Stüwe, 2020), i.e. the transfer of research results to society.

In our study, we focus on the visibility and representation of female scientists on the second level (science communication), namely in German news media coverage about eight science-related risk issues (regulating glyphosate, danger of nitrogen oxides and dioxin, COVID-19, Ebola, pandemic flu, antimicrobial resistance and legalisation of marijuana). We ask

- how often female scientific actors are quoted in media coverage of science-related debates compared to male scientists,
- if the proportion of women and men among scientific actors in media coverage of science-related issues corresponds to the respective proportions of female and male scientists in the relevant research areas and to their hierarchical positions within the scientific system,
- if female scientific actors visible in media coverage differ from male scientists regarding their relative scientific reputation compared to their non-visible scientific colleagues,
- what role the journalists' gender plays in the selection of statements from male or female scientists for media coverage of science-related risk issues,
- and if the content of the statements from female and male scientists quoted in media coverage differs.

What is special about our approach is *firstly* that we answer our research questions from an issue-comparative perspective (instead of a single case study and instead of an issue-independent expert study). *Secondly*, we compare the representation of female and male scientists in media coverage with extra media data (Rosengren, 1970), namely their representation as so-called contributing experts[1] (Collins and Evans, 2002) in corresponding

[1] According to an objectivistic expert definition by the sociologists Collins and Evans (2002: 254), an important form of scientific expertise is when scientists are able "to contribute to the science of the field being analysed", for example through publications. These scientists are the so-called "contributory experts" in the field of research.

scientific research fields (scientists who publish peer-reviewed papers in the relevant fields of research) and their hierarchical positions within the scientific system. *Thirdly*, we take the gender of the reporting journalists into account and test for potential differences in expert selection of male or female journalists. *Fourthly*, we compare the bibliometric profiles of the male and female scientists referenced in media coverage with those of the male and female contributing scientists.

Theoretical background, state of research and hypotheses

Theoretically, our study connects to the perspective of the so-called equality approach (Lünenborg and Maier, 2013), which in general demands that women and men have equal opportunities and can equally participate in society. Therefore, it focuses on the analysis of unequal treatment of women in various areas of society, for example by determining the underrepresentation of women in media coverage. Gender equality is regulated by law both in Germany's Grundgesetz (Basic Law, the German constitution) as well as in European or international human rights law. Related to the topic of our study, the equality approach demands that women are represented in the media on an equal footing.

Another theoretical linking point is the news bias approach, which is about identifying (purposeful) imbalances in media coverage. A basic assumption of this approach is that journalists do not reflect reality, but present it in a biased way. As influencing factors for this bias, the political line of the medium or the journalists' own opinions, attitudes and beliefs are named, among others, which might affect the selection of news and sources for media coverage (Eveland and Shah, 2003). While the majority of studies examines political bias, apolitical bias, such as gender bias, is also the focus of news bias research (e.g. Davis, 1982; van der Pas, 2022).

The question of gender diversity in news media coverage has been scientifically addressed for decades already (in Germany, for example, since the 1970s (Küchenhoff and Bossmann, 1975)). Gender representations in *science reporting* in particular have become an object of research much later (e.g. Huber, 2014; Niemi and Pitkänen, 2017; Prommer and Stüwe, 2020; Soley, 1994). In sum, the state of research seems to be pretty clear: Women are less often referred to as actors or (scientific) experts in media coverage than men, if not even underrepresented in media coverage compared to their occurrence in real life – and this is also true for developed countries with high ranks on gender equality indices (Matthes et al., 2016). This applies to media coverage in general (e.g. Figueiras, 2011; Huber, 2014; Jürgens et al., 2022; Niemi and Pitkänen, 2017; Soley, 1994; Vogler and Schwaiger, 2023; Zoch and VanSlyke Turk, 1998) as well as to science reporting in particular (e.g. Fletcher et al., 2021; Ioannidis et al., 2021; Prommer et al., 2019; Prommer and Stüwe, 2020). Over time, the imbalance of gender representation only moderately improved in favour of women (e.g. GMMP, 2020; Huber, 2014; Schmerl, 2002). According to the latest report of the Global Media Monitoring Project (GMMP, 2020: 20), "[a]ll things remaining equal, it will take at least a further 67 years to close the average gender equality gap in traditional news media." These referenced findings partly suggested a criticism of journalism (keyword 'media sexism'), which allegedly disadvantages women in terms of their public visibility (e.g. Haraldsson and Wängnerud, 2019; Prommer et al., 2019).

However, it should be noted that the proportion of women in media coverage varies depending on the topic (the gender gap is narrower in human interest reporting than in sports or political reporting, for example; Cann and Mohr, 2001; Desmond and Danilewicz, 2010; GMMP, 2020; Prommer and Stüwe, 2020; Schwaiger et al., 2021). For science reporting in particular, latest analyses reveal proportions of female actors in COVID-19 coverage of German- and English-language newspapers of approximately 30-35 percent (Berggren, 2020; Fletcher et al., 2021). In line with that, according to the latest GMMP (2020) report the proportion of female actors in news media coverage of science and health issues is about 30 percent. Therefore, we hypothesize:

H1. News media coverage of science-related issues is dominated by male scientific actors.

In order to show that the proportion of female actors in news media coverage is biased compared to reality and that women are underrepresented in media coverage, most studies compare the determined proportion of female actors in the media with the corresponding proportion in reality (using, for example, data from official statistics). According to Prommer and Stüwe (2020), for example, the gender gap in German COVID-19 coverage on TV amounts to 18 percent. Accordingly, we hypothesize that not only do female scientists appear less frequently than male scientists in science-related news media coverage, but that they are also underrepresented compared to their occurrence in the related research areas:

H2. Female scientific actors are underrepresented in news media coverage of science-related issues compared to their occurrence as contributing experts in the related research areas.

Gender is just one characteristic by which scientific experts can be differentiated. Another important attribute is their scientific reputation. From the perspective of public theory, a decoupling of scientific reputation and media visibility would be problematic, for example if the scientific knowledge about a topic of media coverage stemmed largely from actors who had no scientific reputation on the issue. Latest studies that analyse the connection between the scientific reputation of scientific experts (operationalized by means of publication record) and their selection for German news coverage suggest a positive connection between the publication record of scientists and the selection by journalists – especially in the news medias' specialized science departments (Lehmkuhl and Leidecker-Sandmann, 2019; Leidecker-Sandmann et al., 2022). However, there are also older studies (e.g. Goodell, 1977; Shepherd, 1981) and a recent study by Ioannidis et al. (2021) that use different methods and criteria and cannot confirm such a connection. Thus, the state of research is not uniform and furthermore it is unclear whether scientific reputation of public experts differs between female and male scientists. For example, it is conceivable that female scientists, in order to be considered for a journalistic selection decision, must have a relatively more prominent scientific reputation. We formulate the open research questions:

RQ1a. Do scientific actors visible in media coverage have a relatively higher scientific reputation compared to their non-visible scientific colleagues?

RQ1b. Is this difference more pronounced for female or male visible scientific experts?

In addition, there are studies that consider a potential influence of the journalists' gender and examine whether this correlates with the selection of male or female experts for media coverage. Zoch and VanSlyke Turk (1998), Huber (2014), and GMMP (2020), for example, show that female journalists are significantly more likely than male journalists to reference female experts or sources. "There is a consistent 5-7% point gap between women and men reporters on female source selection" (GMMP, 2020: 7). Therefore, we assume:

H3. The gap between references to female and male scientific actors in media coverage of science-related risks will be smaller in articles authored by women than in articles authored by men.

Last but not least, we are interested in the content of the statements from female versus male scientists. Some studies suggest that female scientific experts tend to express themselves more cautiously and as neutrally or objectively as possible in public discourse and are less likely to make action-related (political) recommendations (e.g. Niemi and Pitkänen, 2017; Shine, 2022). Therefore, we hypothesize:

H4. Referenced female scientists in media coverage less often communicate (political) recommendations within their quoted statements than visible male scientists.

Data and method

Issues

To test our hypotheses and to answer our research questions, we conducted standardized quantitative content analyses of eight risk issues, which we have grouped according to the importance given to scientific experts in these debates. The issues antimicrobial resistance (AMR), Ebola as well as two potential pandemic flu debates in Germany on swine flu (2009) and bird flu (2005/2006) are characterised by the relative dominance of scientific expert voices and the relatively subordinate importance of political actors. In all three issues, scientific experts account for more than 40 percent of all references in the media articles we analysed (see 'data'). In contrast, there are four debates (on the regulation of glyphosate, dioxin, nitrogen oxides (NOx) and on the legalisation of marijuana) in which scientific expertise played a much less important role. All four issues are dominated by political actors and revolve around concrete political decisions that are flanked by scientific expertise. References to scientific experts account for less than 20 percent of all references. The media debate on COVID-19, our eighth issue, must be described as absolutely exceptional in many respects (e.g. amount of coverage; Eisenegger et al., 2020) and therefore be distinguished from both groups. In relation to the criterion chosen here, in purely quantitative terms, this debate was not dominated by scientific experts. In fact, especially actors from the political executive and representatives of partial interests were strongly present within the news media coverage of COVID-19 (Leidecker-Sandmann et al., 2022). Nevertheless, qualitatively scientific expertise played a decisive role in various political decisions, especially lockdowns. This in combination with the huge amount of media reporting led to a general impression that during the COVID-19 pandemic scientific experts have been more present in media coverage than perhaps ever before. Overall, a triad of important actors emerged, including scientists, the political executive and lobbyists.

Data

We analysed the coverage of the eight issues mentioned above between 1995 and 2020 in four German media titles: the national daily newspapers *Die Welt* and *Süddeutsche Zeitung*, the weekly news magazine *Der Spiegel* and the news agency *dpa*. We collected corpora of thematically relevant articles via keyword searches[2] in the databases *wiso presse* (*Die Welt* and *Der Spiegel*), *SZ LibraryNet* (*Süddeutsche Zeitung*) and *dpa-news.de* (*dpa*).

This study presents a detailed analysis of the results of several content analyses that have been carried out over the past ten years using the same instrument. Only a specific section of the total data material (of which Table 1 provides an overview) is relevant for this study, namely only references to individual scientific experts.

Table 1. Data basis per issue

	Articles	**References (All)**	**References to individual scientific experts**	**Actors (individual scientists)**	**References to individual life scientists**	**Actors (individual life scientists)**	**Investigation period**
AMR	152	358	126	92	116	84	1997-01-01 - 2013-12-31
Potential pandemic flu	175	534	166	107	161	102	1996-01-01 - 2015-12-31
Marijuana	234	693	64	40	51	31	2012-01-01 – 2019-05-31
Glyphosate	298	609	71	42	65	36	2015-01-01 - 2019-12-31
Ebola	330	991	171	100	164	96	1999-01-01 - 2019-12-31

[2] The German keywords were: *COVID-19*: Corona*, Covid*, Corvid*, nCov*, n-Cov*, SARS*, Wuhan und Lunge*, Wuhan und Krankheit, China und Krankheit, China und Lunge*; *Flu pandemics*: schweinegrippe oder (pandemie AND grippe); *Ebola*: Ebola*; *Antimicrobial resistance*: antibio* AND resist*; D*ioxin*: Dioxin*; *Nitrogen oxides*: ((stickoxid*) OR (stickstoffoxid*) OR (stickstoffmonoxid*) OR (stickstoffdiox*) OR (NOx)); *Glyphosate*: glyphosat* oder herbicid*; *Marihuana*: (Marihuana* OR Cannabi*) AND Legalisier*.

NOx	489	1183	166	94	122	68	2011-01-01 - 2019-06-30
Dioxin	997	2319	229	153	188	124	1995-01-01 - 2015-12-31
COVID-19	2185	6382	776	496	609	363	2020-01-01 - 2020-12-31
All	**4860**	**13069**	**1769**	**1124**	**1476**	**904**	**1995-01-01 – 2020-31-12**

The detailed analysis is based on a total of 4860 articles that appeared between 1995 and 2020, drawn by stratified random samples that comprise between five and ten percent of all articles, depending on the issue. In these articles, we identified about 13,000 references to different actors, of which almost 8800 are attributable to individual actors, the rest to organisations such as the WHO, Greenpeace, etc., without an individual actor appearing as a spokesperson. A reference is defined as a passage in which one or more statements of an actor are quoted (directly or indirectly). Of these 8800 references, about 1800 relate to individual scientific experts (20 %), 1500 relate to experts from the life sciences. They come from the 1124/904 different scientific experts at the centre of this study.

In addition, we have gathered *extra media data* by analysing a random sample of 2400 scientific experts (300 experts per issue). The prerequisite for the inclusion in this sample was the publication of at least one scientific paper as first or last author (in which at least one person with German affiliation was involved) in research areas corresponding to the eight analysed issues between 1995 and 2021. The resulting list of life scientists are the so-called contributing experts according to Collins and Evans (2002) and represent our *control sample*. The control sample was formed in four steps: Step 1: Keyword-based compilation of all publications with German affiliation in relevant research areas via the database *Web of Science*. Step 2: Extraction of all first and last authors. Step 3: Name disambiguation: multiple spellings of a person's name have been merged. Step 4: Random selection of 300 scientists per issue. Table 2 provides details on the composition of the control sample.

Table 2. Number of contributing experts from publications with at least one German affiliation, from which a random sample of 300 experts each was selected

Issue	N Experts	Searchstring
AMR	6669	(antibiotic* OR antimicrobial*) resist*
Corona	10,783	virology OR (epidemiology and infectious diseases)
NOX	6621	nitrogen dioxide OR "nitrogen oxide" OR NOX
Glyphosat	534	Glyphosate
Dioxin	5875	(dioxin* OR PCB OR PCDD OR PCDF OR furan* OR polychlorinated byphenil* OR polychlorinierte* Byphenil* OR TCDD OR TCDF OR PBDD OR PBDF OR PFDD OR PFDF)
Influenza	3029	Influenza
Ebola	382	(ebola* OR filovir*)
Marihuana	3108	Cannabi* OR Marihuana* OR Marijuana* OR Dronabinol*

For the scientists in our control sample we coded their gender according to the method used for the quantitative content analysis (see 'measurements'). From this reference sample, we derive the proportion of female and male researchers who actively publish in a specific research area. Additionally, we determined the scientific reputation of all contributing experts and estimated the share of male and female researchers in scientific leading positions in the respective research fields. We operationalized leading positions via the order of authorship: scientists that appeared at least three times[3] as last-named authors were defined as scientists in senior roles as it is common practice, particularly in hard sciences, that the leader of a research group is credited with last authorship (Müller, 2014).

Measurements

We distinguished two different levels of analysis: the *individual actor level* and the statement or *reference level* in order to study not only the representation of individual experts

[3] We have opted for a minimum of three last-authorships in order to be able to more reliably identify the scientists in higher hierarchical positions – the more frequently they serve as last authors, the greater the likelihood that they are group leaders. Our results are relatively robust to slight changes in this criterion. Still, we cannot ensure that all the last authors of scientific publications actually work in a senior position, but can only provide an approximation of the actual value.

but also the reference pattern. At the actor level, each person is counted only once, no matter how often they are referenced. For the reference level, we count each reference, so one person can appear multiple times. The actor level analysis includes bibliometric comparisons with the control sample and had thus to be restricted to the 904 life scientists. For other scientists such a comparison is not manageable. The reference level analysis is not restricted to life scientists. It includes references to all 1124 visible individual scientific experts.

For each actor, we coded the *name*, *institutional and national affiliation*, and *affiliation to a societal area* (such as political executive, partial interest group, science). For all scientific actors as well as for the author of the news article, we additionally coded the *gender* – our central variable – using a category with three values (male, female, other/not known[4]). The gender of the *scientific actors* was automatically coded using the platform *Namsor*. All cases for which the certainty of the procedure was below 90 percent were coded manually (213 cases), as were 100 cases for which only initials were available.[5] Here the procedure was as follows: Firstly, an attempt was made to make a classification based on the name and personal knowledge of whether a name is more commonly used for male or female persons. If coders were unsure, they secondly searched for the scientist's name using *Google* and looked at up to three hits to arrive at a classification. The gender of the *authors of the articles* was classified manually (determination based on the first name as well as pronouns or the use of other male or female terms).

Coding was done by 13 coders that had all taken part in an intensive training course held by the project leader using the same training material. To ensure coding quality, all

[4] Although we are aware that the use of a simple 'male-female' category narrows the facets of gender with their respective sub-dimensions, more differentiated classifications were not possible based on the journalistic content.
In cases where a media article was written by several authors of different genders, "mixed" was coded.
[5] For all other cases, the procedure delivered highly reliable values. We tested the validity of the procedure by having three coders manually categorize a total of 1728 personal names. We then had the same names encoded automatically via *Namsor*. The agreement between manual and automated coding is .99 according to the Holsti coefficient respectively .977 according to Krippendorff's alpha.

coders had to complete multiple intercoder reliability tests. In the final test, all coders categorized the same 20 articles and up to 29 actor statements and reached satisfactory to very good results for the variables on the actor level (Krippendorff's alpha: .75-1).

To assess the scientific *reputation* of the visible scientists, we collected the bibliometric profiles of all life science experts who were mentioned by name in the articles. We used the *PubMed Europe* database, which primarily contains biomedical publications. Experts from other fields have not been analysed. In our analysis, we focus primarily on productivity and impact, operationalised by the total number of publications in Q1-Q3 journals and the h-index[6]. Q4 journals were excluded because they are unlikely to be relevant for reputation building, at least for German life scientists.

For each issue, we compared the bibliometric indicators of the visible scientists with those of the control sample of 2400 experts. The control sample represents the average reputation of researchers in Germany in the fields relevant to the issues analysed. The individual publication profiles of the experts were retrieved with the help of a Python script that automatically retrieves the data from the *PubMed Europe* API. The program is published together with a detailed description of how it works (Milhahn et al., 2018).[7]

Results

Representation of female life scientists in news media coverage

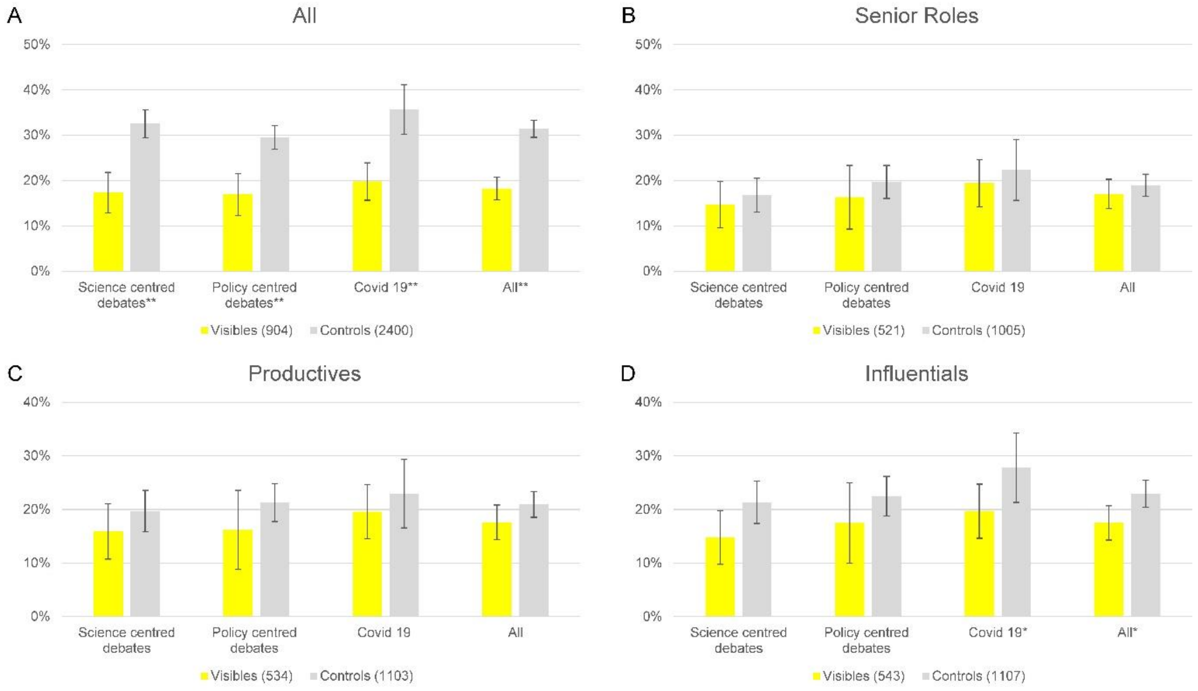
Simple frequency counts at the actor level prove that news media coverage of science-related issues is dominated by male scientific experts (82 % versus 18 % female scientific experts), confirming H1. However, whether female scientists are actually *underrepresented* in

[6] The h-index is a key metric for the global perception of a scientist in professional circles. It is based on bibliometric analyses of citations to the scientist`s publications. A high h-index results when a significant number of a scientist`s publications are frequently cited in other publications.
[7] The results were validated by comparing them with manually collected publication profiles of 229 researchers. We used *Scopus* for this validation. The number of publications correlated with r=.72 and the h-index with r=.77.

media reporting compared to their occurrence as contributing experts in the respective research areas (H2) can only be seen by comparing these values with those of our control sample of contributing scientists in the respective fields of research. This comparison shows that female life science experts are indeed also significantly underrepresented in public media debates compared to their share of actively publishing scientists in the respective fields (the control sample). Their share of visible life scientists (18 %) is 13 points lower than their share in the research fields (31 %). This underrepresentation applies to all eight individual issues, which we have summarised into three groups depending on the quantitative or qualitative importance of scientific actors (Figure 1A). This value corresponds to the proportion of women reported in the studies by Huber (2014) or Soley (1994), but is well below the value of Berggren (2020), Fletcher et al. (2021) or GMMP (2020) (values between 30-35 %). This may be explained by the fact that the latter refer to the share of women among *all* actors within science and health coverage (GMMP, 2020) respectively so-called experts in COVID-19 coverage (Berggren, 2020; Fletcher et al., 2021), without specifically focusing on *scientific* experts as we did.

While this simple comparison confirms our second hypothesis, we would like to test the robustness of this finding through further, more differentiated analyses. For these differentiated analyses of the proportion of women, we harmonised our two groups of scientific experts (visible scientists and control sample) with regard to three characteristics: 1) we only compared those who work in senior roles (Figure 1B). In addition, we analysed the 2) most productive and the 3) most influential scientists separately. These last-named two groups include those who have published more than half of all others (most productives) or whose papers have been cited more frequently than those of half of all others (most influential) (Figure 1C and 1D).

Figure 1: Female shares of visible experts compared with female shares of a random sample of contributing experts by issue group (95 % CI)



The difference in the proportion of female experts between the visible scientists and the control sample is then significantly reduced to two to five points. However, although women in senior roles are only slightly underrepresented ($\chi^2(1)= .85; p=.36$), the difference is systematic in all three issue groups. The difference is somewhat greater across all issues when comparing only the productives ($\chi^2(1)=2.5, p=.11$) and the influentials ($\chi^2(1)=6.5, p=.01$). It follows that the large difference in the proportion of women in media coverage is primarily due to the group of experts who do not hold senior positions, have published comparatively little and have a comparatively low impact.

However, a more differentiated look at the visible experts in this group (no senior position, little publications and low impact) in particular indicates that a simple comparison with the control sample is only of limited significance. This is because among them the proportion of functionaries in science-related (non-)governmental organisations, like heads of department, senior physicians, heads of local health authorities etc., is comparatively high, namely around two thirds (in the group that has published comparatively much, it is just under one third). Therefore, it must be taken into account that the visible experts are not a homogeneous group of researchers.

Our sample of visible experts consists of scientists who work at universities or other research institutions and whose primary tasks include research as well as of many managers in governmental and non-governmental organisations. Their public spokesperson role is not primarily legitimised by their scientific expertise, but by their professional role in a non-scientific context. An internationally known example is the *Robert Koch Institute*, which is a federal government agency attached to the *Ministry of Health* that also has research tasks, but essentially fulfils specialised government administrative and supervisory tasks. Hospitals are another example, where research is also carried out, especially in university hospitals, but where many scientific experts also work who do not carry out research themselves.

Because of the high proportion of functionaries in the group of those visible experts with comparatively few publications, a comparison with the control group of contributing experts appears to be at least distorted, because the reference value for the interpretation of the proportion of women in this group is not the proportion of women in the research fields that includes many junior scientists, but the proportion of women in leading management positions, especially in science-related state specialist administration and medicine.

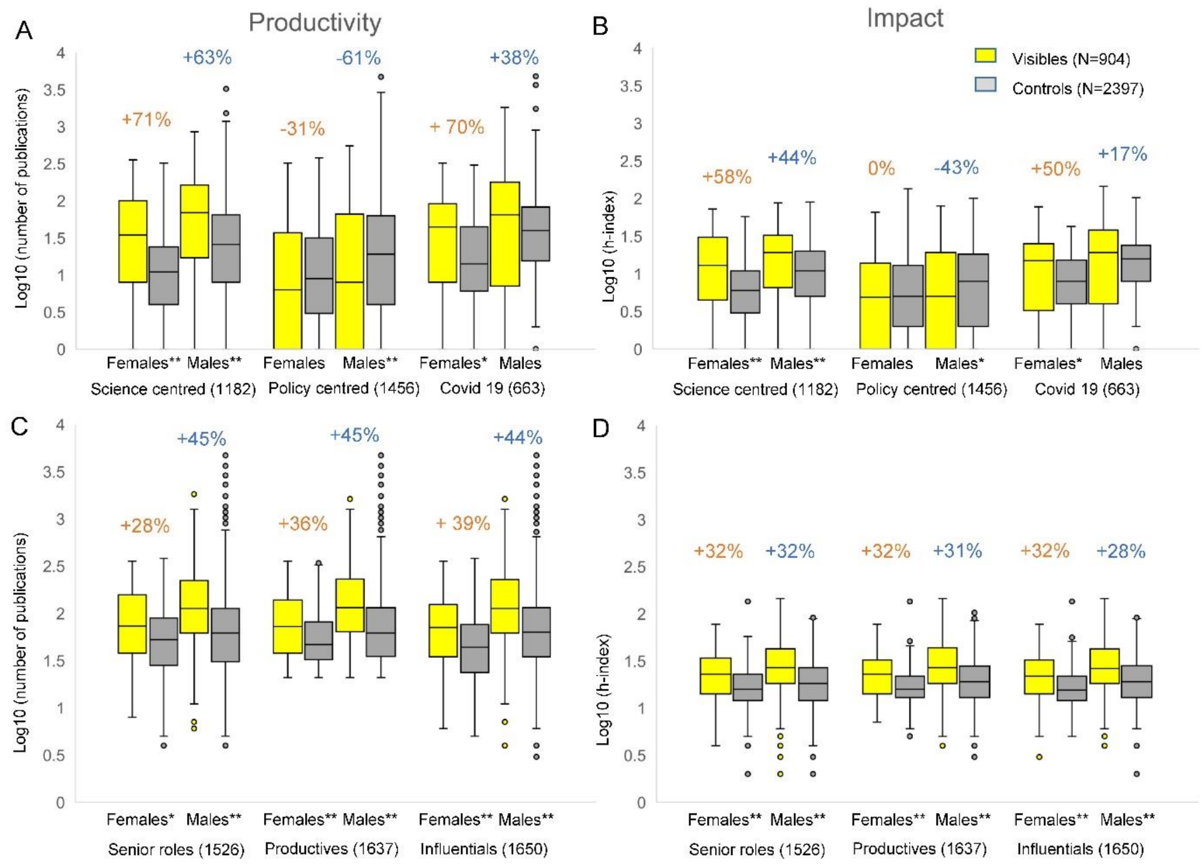
To summarise our findings, we can confirm that female scientific experts are less visible in media coverage compared to male experts (H1). Further, in terms of their representation measured by their share in the research fields, visible female experts are clearly underrepresented (H2). However, when we control for hierarchical position, productivity and impact, the findings are no longer unambiguous. The differences become so small that they stay predominantly within random fluctuation margins.

The difference in the proportion of women is significantly greater in the group of experts whose selection is primarily based on their professional (instead of their scientific) role. However, the high proportion of functionaries in this group does not allow a reliable assessment of whether this difference is due to a selection bias or due to gender disparities in the filling of management positions.

Reputation of female and male life scientists in news media coverage

In the next step, we want to analyse the relationship between reputation (number of publications in Q1-Q3 journals and h-index) and public visibility to answer our research questions (RQ1a and RQ1b). For this task, we also harmonised the visible scientists and the control sample in terms of hierarchical position, productivity and impact (Figure 2C and 2D). Our analyses show that across all issues, the visible scientists of both genders in these subgroups have a significantly higher reputation than the controls (Mann-Whitney U test $p < .001$). However, a comparison of the issue groups shows that this does not apply to all issues (Figure 2A and 2B).

Figure 2: Boxplot of productivity and impact of female and male experts by issue group (Mann-Whitney U-test *<.05;<.001), y-axes logarithmic/ Reputation gap by gender in percent**



Measured in terms of productivity and impact, visible scientists have a significantly higher reputation only in four of the eight issues (Mann-Whitney-U-Test $p < .001$). These are the four issues in which scientific expertise is of comparatively high relevance (AMR, Ebola, Pandemic Flu and COVID-19). Accordingly, we only find a positive correlation between reputation and visibility in debates in which scientific expertise can be attributed a significant role.

This applies to both women and men. For the differentiated analysis, we determined the "reputation gap" between the visible experts and the respective control groups. For the calculation of the reputation gap, we determined the medians of the number of publications and h-indices as a basis and set them in relation to each other. The basis for the comparison is always the control group. If the group of visible experts has a median of 10 publications and the control sample a median of 15, the gap between the two groups is -33 percent. These differences provide information on whether the reputation gap between visibles and controls is greater (or smaller) for women than for men. Based on this comparison, we can therefore estimate whether visible women have a higher or lower reputation gap compared to visible men, with the respective control group serving as a reference.

Such a comparison is preferable to a direct comparison between male and female scientists because this would require taking into account various control variables that were not recorded in this study. As Figure 2 shows, women have lower scores than men in every category. However, this does not necessarily indicate that they have a lower reputation. Direct reputation comparisons between men and women must at least control for differences in career duration and affiliations, which was not possible in this context (Boekhout et al., 2021; Huang et al., 2020).

The particularly robust comparison of the three subgroups of the productive, the influential and the scientists in senior positions indicates that visible female experts differ slightly from men in terms of productivity at best (Figure 2C and 2D). We interpret this finding to mean that female experts do not need to be relatively more productive or relatively more influential compared to the relevant scientific community than men in order to be referenced by the German quality press.

However, we also find differences in the three issue groups with regard to this characteristic. In the science centred debates, the gap in productivity and impact between visibles and controls is approximately the same for both women and men (Figure 2A and 2B). But we find a difference in the expected direction in the policy centred debates and in the COVID-19 debate. This indicates that different selection dynamics may take effect for women than for men depending on the issue.

Reference patterns

So far, we have only looked for differences at the level of the individual actors referenced by journalism and have not focussed on differences in the referencing. We therefore now want to investigate whether the individual experts are referenced differently by journalism depending on their gender. In addition, we want to analyse whether the gender of the journalists influences the referencing of female experts. Accordingly, in the next step of the analysis, we change the unit of analysis. Instead of actors, we focus on references. Other than in the step before, we are no longer restricted to life scientists only and include all references to scientific experts in the analysis. This increases the number of visible experts from 904 to 1124 (see Table 1).

In order to uncover potential differences, it is first relevant whether there is a difference between the female share at the actor level (18 %; N=1124) and the female share at the reference level (N=1769), which is 17 %.[8] This indicates that female experts are slightly less frequently cited than male experts. On average, each female expert is cited 1.5 times, male experts slightly more, namely 1.6 times (F=.30; p=.58) (Figure 3A). The gender of the selecting journalist only has a small influence on this characteristic; male authors cite female experts almost as often as female authors (1.4 times vs. 1.7 times on average (F=.96; p=.33)).

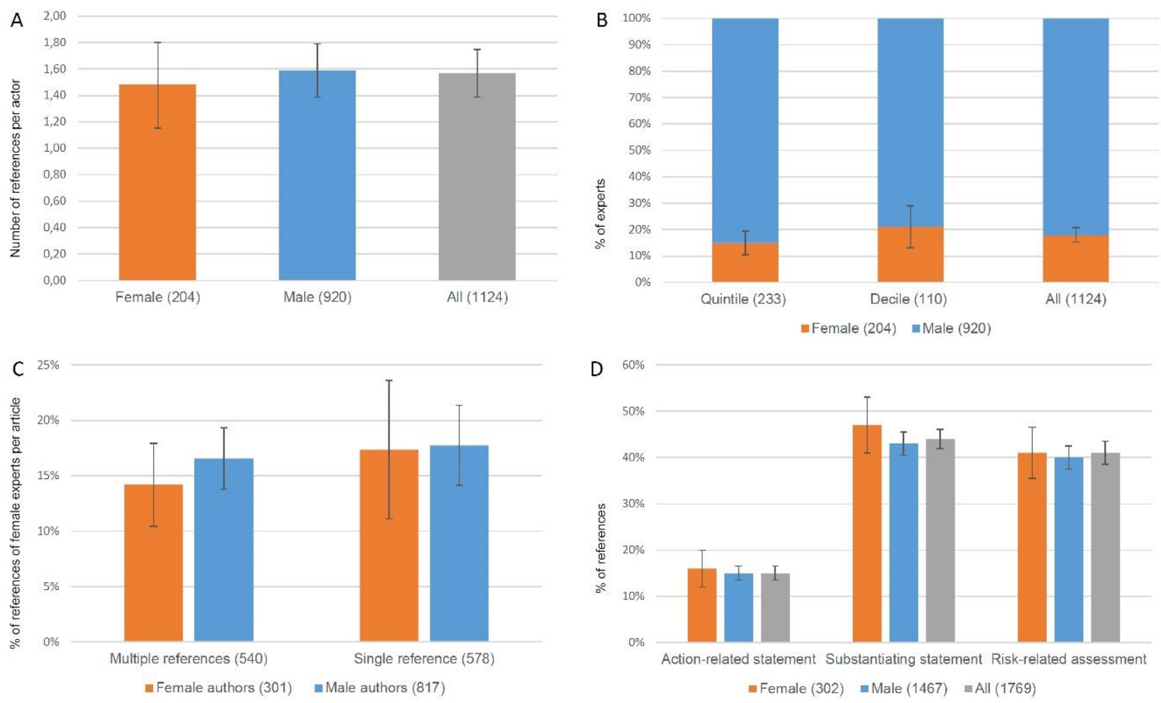
However, mean value comparisons are not sufficient in themselves to adequately describe the referencing practice in journalism because the references are quite heavily skewed to the right. The vast majority of experts in our sample were only quoted once, only around 20 percent were quoted somewhat more frequently, and some were quoted very frequently during the COVID-19 debate.

In order to draw a differentiated picture, we have therefore grouped the referenced scientists according to whether they are quoted more frequently than 80 percent of all other

8 At the actor level, this value indicates the percentage of visible experts that are female; at the reference level, it indicates the percentage of references to female experts.

experts (the upper quintile). In addition, we identified the top referenced experts who were cited more frequently than 90 percent of all other experts (the upper decile). We find that female scientists are slightly underrepresented in the top quintile (15 %), but slightly overrepresented in the top decile (21 %) (Figure 3B).

Figure 3: Comparison of referencing patterns of female and male experts (95 % confidence interval)



The comparison of whether female journalistic authors differ from male authors in their referencing patterns does not yield a positive result for this attribute either. Female authors cite the upper quintile of female experts 4.7 times, male authors 3.5 times (F=1.0; p=.32).

To sum up, we cannot find any reliable evidence that individual female scientists are on average referenced less often than men. Furthermore, the separate analysis of the two subgroups of top-referenced scientists (quintile and decile) does not provide any consistent evidence of discrimination by German print media. The second level of comparison, that between female and male journalists, does not yield a positive result either. Therefore, we have to reject H3.

However, references to individual actors do not provide any information about the context in which they are embedded. In the majority of cases, articles in our sample contain more than just a single reference. They are usually compositions of several references to several actors. Therefore, we analysed in a last step, whether female expert voices are differently represented in longer background articles with more than just one expert voice compared with articles that cite just one expert. This would indicate a gender-related difference in referencing practices on female experts in German print journalism. We determined the proportion of statements made by female experts for each article (Figure 3C). The proportion is 16 percent in longer background articles with multiple references to experts and 18 percent in articles with only one reference to an expert, which corresponds to the female share of all references, which is 17 percent. Meaningful differences depending on whether the author of the article is female or male cannot be found.

Content of statements

Any gender-related differences in what the experts say have not yet been taken into account. For the quantitative structural analysis of the content of expert references, we distinguish between three types of statements (based on the decisionist model of political advice (e.g. Weber, 1922)), namely substantiations (e.g. 'we had X nosocomial MRSA infections last year'), risk interpretations (e.g. 'the situation is worrying/not dramatic'), and action-related political or individual recommendations (e.g. 'shops should remain closed', 'you should wash your hands more often'). As Figure 3D shows, the structure of the statements with which the experts appear in public does not differ at all between the genders. Both groups of experts are reluctant to make action-related statements; the majority of statements are substantiations or risk-related interpretations. We have further differentiated these statement types in terms of their content. We differentiated the action-related statements according to the addressee of the request (politics, civil society or individuals), the substantiations according to how precise they are, and the interpretations according to whether they are more alarming or reassuring. This detailed analysis also revealed no evidence that the statements of the female experts differed from those of the male experts (refuting H4). How experts express themselves publicly or how they are quoted seems to be determined by their expert role and does not appear to be influenced by the gender of the speaker. Accordingly, the search for differences between female and male authors does not yield any positive results in this step of the analysis.

Summary and discussion

Our analysis shows that female scientific experts play a subordinate role compared to male experts in German media coverage (H1). Regarding the equality approach, it is clear that there is still a long way to go before there is 50/50 representation in the media public as well as in the scientific sphere. However, this study focussed on the question of whether female scientific experts are also underrepresented (in the sense of a media bias) when measured against normative reference values other than 50/50 representation. Our comparisons with the control sample of contributing experts indicate one thing: The more differentiated the level of comparison regarding the representation of female experts, the smaller the differences become. However, they do not disappear. Even after controlling for hierarchical position and reputation, the proportion of women among visible life science experts remains systematically below the reference values from the research communities, which indicates imbalances or biases in media coverage. However, the differences become rather small and generally remain within random statistical fluctuation margins. The differentiated findings presented here thus fundamentally suggest that female experts are underrepresented in the public sphere, confirming H2. At the same time, they relativize the extent of the problem (keyword ‘media sexism’) considerably.

The study also looked for evidence of possible discrimination against female scientific experts through journalistic selection routines, which could at least partially explain the public underrepresentation of female experts. By and large, the findings are negative. There is no evidence of a general discrimination in any of the selected research dimensions. In detail: Female experts are not quoted significantly less frequently by male journalistic authors than by female journalistic authors (refuting H3); the focus on individual, particularly visible experts is hardly less pronounced for women than for men; and the content with which they are quoted does not differ from that of men (H4). Regarding the scientific reputation, the findings are a bit more ambiguous: Female scientific experts do not require a reputation that is superior to that of men in order to be referenced by journalists in the science centred debates. In policy centred debates and in COVID-19 coverage, the gap in productivity and impact between visible scientists and the control sample is more pronounced for women than for men. However, it is not clear whether this should be interpreted as a bias due to journalistic selection routines.

Taken together, the detailed analysis of the reference patterns in German quality press provides no clear evidence of discriminating referencing practices through journalism. Our findings therefore in a sense contradict previous analyses that accuse journalism of media sexism or a gender bias (e.g. Haraldsson and Wängnerud, 2019). Rather, we would say that the hierarchical position, the productivity and the impact that female or male scientists have in their research field seem to be the more decisive factors than their gender. Expressed differently: Since fewer women work in high scientific positions than men, since they publish less and since their publications have less impact than those of men, they are also less likely to be selected as sources for science reporting (Huber, 2014). To put it bluntly: Journalism mostly reflects the unequal opportunities within the academic system.

On the downside, we do not find any relevant evidence that structural gender inequality is significantly mitigated by sourcing practices through journalism either. (Mass) Media do not only depict realities of society – they also (help to) construct them (Tuchman, 1978). In this respect, more female role models in news media coverage of science-related issues could possibly increase women's confidence to gain a foothold in the respective male-dominated scientific research areas.

In the context of this study, we cannot answer which factors are relevant for the (non-)selection of female scientists. However, we suppose that the negative findings regarding a systematic journalistic discrimination of female scientists draw attention to the somewhat stricter self-selection of female experts, as indicated by some studies (e.g. Howell and Singer, 2017; Shine, 2022). This could be one possible explanation for the differences documented here.

Of course, there are other factors than gender according to which journalists select experts for media coverage like availability and reliability, media experience, attractive appearance, ability to articulate, strength of opinion, or predictability of the statement (e.g. Nölleke, 2013). Hence, it is not one criterion alone that makes an actor newsworthy, but rather a bundle of factors (Peters, 2014) which we were unable to take into account in the context of the present analysis.

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Declaration of Conflicting Interest

The author(s) declare(s) that there is no conflict of interest.

Data availability

The datasets generated during and/or analyzed during the current study are available in the figshare repository https://figshare.com/s/f04dff6083cb6af055bb. If you are interested in further data, please contact the author(s).

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