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Gender differences in grant submissions and research topics. An approach to study proposals of the Experiment! program of the Volkswagen Foundation across science and engineering fields

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Abstract

Research persistently shows that women are underrepresented in most science and engineering fields and obtain fewer research grants than men. In this paper we consider gender-related interests to investigate female and male scientists' rates of submitted grant proposals and their selection of research topics in research areas of life science, engineering science, physical science and mathematics. Do men and women differ in their research preferences? Do they vary in respect of numbers of submissions and topics? To study submission rates, we analysed data about applications of the *Experiment!* Grant programme of the German Volkswagen Foundation to do unconventional research. To identify research topics, we additionally applied an LDA-based topic model. The findings reveal uneven proportions of submissions among men and women in different research areas. Regarding research themes, results suggest that men dominate in more topics than women.

Key words: research proposals, submission rate, research topic, gender, research interests

Gender inequality in science

In science, women are disproportionally present in different research areas. They are underrepresented in engineering science, physical science and mathematics compared to life and social sciences, which are relatively balanced (Mann & DiPrete, 2013; Ceci et al., 2014; Leslie et al., 2015; van der Vleuten et al., 2016; Cheryan et al., 2017). Such gender-related disproportions are also evident within these research areas. Women and men who study engineering science, for instance, vary in their choices of majors (Ihsen et al., 2014; Naukkarinen & Bairoh, 2020). These uneven proportions continue in graduate school programs and in further academic positions (Ceci et al., 2014), and they are also evident when female and male researchers ask for funding. Different studies show (Hosek et al., 2005; van der Lee & Ellemers, 2015; European Commission, 2018; Rissler et al., 2020) that the number of female applicants is higher in social sciences and humanities and lowest in engineering science, physical science and mathematics. There are various explanations for women's lower rate of submitting grant proposals and rate of return, ranging from discrimination over differences in productivity to distinct interests and attitudes. Most studies in this regard examine gender bias in review processes of funding programs (Wennerås & Wold, 1997; Kaatz et al., 2015; Witteman et al., 2019) and applicants' scientific productivity (Abramo et al., 2009; Lariviere et al., 2011; Huang et al., 2020), suggesting that lower success rates are responsible for women's lower rate of submissions.

However, it is remarkable that gender-related interests are considered when scholars investigate differences in college majors and professional (academic) choices but that scholars rarely study whether female and male applicants vary in their selected research preferences. Do women in their research proposals concentrate on different topics than men? We know very little about their choices of research topics. There are only three studies to our knowledge that showed independently that female applicants concentrate on certain research topics in sociology (Allmendinger & Hinz, 2002), political science (Key & Sumner, 2019) and medicine (Burns et

al., 2019). What about life science, engineering science, physical science and mathematics? We know that girls prefer careers as physicians, veterinarians, teachers, nurses, and so on (Ceci et al., 2014), but do female researchers also concentrate in their planned investigations on certain research topics? Are there gendered proposal topics across science and engineering fields?

In this paper, we take up these questions and investigate gender proportions of submitted proposals and test an approach to study research topics in a funding program open for the life sciences, engineering science, physical science and mathematics at the Volkswagen Foundation. Applicants came from a broad range of research areas and submitted grant proposals to do initial and unconventional research. In this regard, we determined the relative difference between men and women in submission rates across science and engineering research areas. Finding different submission rates for women and men in distinct subfields we further employed an LDA-based topic model to an accessible sample of proposals to search for research topics and check gender-related variations and concentrations on specific research topics.

This observational study shows that proportions of women are not the same as their submission rates for this special funding program dedicated to support exceptional research. In certain research fields, women are more active. Moreover, looking at research topics, men significantly dominate various research subjects related to physical and technical sciences whereas women are only overrepresented in one topic concerned with human health. Nonetheless, findings also suggest that women tend to dominate other research topics as well but it will need additional research to find more substantial empirical evidence. Based on these preliminary findings, we assume that thematic concentrations might translate into submission rates because concentrations on certain research topics could lead to increased competition resulting in lower rates of submissions and success. Otherwise, underrepresentation in other research topics may decrease the chances of being funded there. Results, however, suggest a need for further research to deepen our understanding of the impact of gendered research foci on rates of

submission and funding success, especially if compared with relatively higher rates of submissions but with less success for women in highly competitive funding schemes in social science and medicine.

1. Previous research

Studies on gender proportions in different research areas (Mann & DiPrete, 2013; Ceci et al., 2014; Leslie et al., 2015; Cheryan et al., 2017; Rissler et al., 2020) report that women are underrepresented in engineering science, physical science and mathematics. It is especially true for physics, engineering, and computer science, compared to life and social sciences, which are relatively balanced. In the United States, for instance, Ceci et al. (2014) observe that women received only 25% of bachelor's degrees in mathematically intensive fields and women are significantly overrepresented in non-math-intensive fields, receiving almost 70% of these bachelor's degrees. In other words, most women choose to study life science, psychology, and social science, if they have preferences for these majors. Leslie et al. (2015) show these disproportions are also evident for getting Ph.Ds. in the United States. In this regard, women earned approximately half of all in molecular biology and neuroscience degrees, but less than 20% in physics and computer science. In this respect, Mann and DiPrete (2013) present a set of counterfactual analyses to demonstrate the continuing and substantial role of preferences (net of test scores) in predicting the major choices of women and men and how these changing preferences are greatly increasing the number of women in STEM fields but in the direction of life sciences, not physical sciences, or engineering sciences. Recent investigations support the observation of persistent gender segregation in science, narrowing in many research areas with trends in life science of more women than men in the United States (Cheryan et al. 2017) and in other countries (Huang et al., 2020; for Australia: Law, 2018; Finland: Naukkarinen & Bairoh, 2020; Germany: Hägglund & Lörz, 2020).

However, gender differences in engineering science, physical science and mathematics are not only found at aggregated levels but also within research areas. Especially for engineering with the largest gender difference in interests (Su & Rounds, 2015), recent studies disclose that young female and male students are attracted to different subfields. Naukkarinen and Bairoh (2020), for example, found that gender distribution in engineering sciences ranged from fewer than 10% of the female applicants in electrical engineering and energy technology (7%) as well as in mechanical and automation engineering (8%), to close to half in environmental engineering and biotechnology (46%), and more than half in architecture and landscape architecture (62%) in Finland. Almost similar in Germany, Ihsen et al. (2014) show that female students in engineering concentrate their majors in specialization areas, such as ophthalmic optics, clothing engineering, health, and environmental technology.

After graduation specialization continues and is pivotal to advance in academic careers. According to Leahey (2006), especially tenured professorships at universities give priority to early specialization of researchers. It is assumed that a scholar's specialization allows him or her to gain in-depth knowledge of a particular research field (including related theories, concepts, and methods) providing the basis to build on it and broaden further research. In fact, Leahey and colleagues (2008) show that specializations increase during the academic career processes, with men more specialized than women at the beginning and at the end of their careers.

Interestingly, we know little about gendered research preferences and specialization in research funding processes. Previous research concentrated mainly on gender-related differences concerning submission and success rates. Various studies show that female applicants are underrepresented in research areas of life sciences, engineering science, physical science and mathematics and more balanced in humanities and social science (Hosek et al. ,2005; van der Lee & Ellemers, 2015; European Commission, 2018; Rissler et al., 2020). Nonetheless, gender segregation is not only evident in different research areas but also within these areas. In

engineering science for example, according to the German National Science Foundation (DFG, 2017), a relatively small proportion of female scientists (20.0%) asked for funding. A closer look at the subfields indicates that the smallest proportion of female applicants is affiliated with informatics, system and electrical engineering (15.3%). In contrast, the number of women is greater in heat and process engineering (23.3%), material engineering (24.2%), and up to 32.2% in civil engineering and architecture. Hence, within a research area such as engineering science, women are represented differently with greater proportions of female scientists in some subfields with research activities on particular topics related to architecture, biotechnology, and environmental issues.

Most research on gender differences in grant proposal submissions and funding rates examines certain funding programs dedicated to specific research areas. To our knowledge, there are only two investigations that studied in detail research topics of grant proposals related to the applicants' gender and one that examined gendered topics in dissertations in political science. Allmendinger and Hinz (2002) observed grant proposals in Sociology for the DFG between 1993–1999 and found that almost half of all applications submitted by women could be categorized as gender-oriented research. In contrast, Burns et al. (2019) examined submissions to the Canadian Institutes of Health Research (CIHR) and revealed that women in general had significantly lower grant success especially in research content areas such as cancer research, circulatory and respiratory health, or health service and policy issues. Female compared to male applicants in contrast submitted more grant applications for research topics in content areas of health services and policy, aboriginal peoples' health, and gender and health. Key and Sumner (2019), in addition, investigated not grant proposals but the content of dissertation abstracts and found gendered topics in political science. It appeared that topics systematically associated with women include race, gender, healthcare, narrative and discourse, and branches of government. Men in contrast dominated topics such as voting, campaigns, congress, and interstate war.

Against this background, previous research has demonstrated that initial academic orientations and preferences are shaped early in childhood and when young women and men enter colleges and universities, continuing across their life course in the academic world. In fact, incorporated interests seem to affect careers choices and get solidified in further specialization processes. In this study we focus on submitted proposals and selected research preferences. Do female scientists in particular take up different research topics compared to their male counterparts? Are there gendered research topics across science and engineering fields? To do so, we take a closer look at applications sent to the *Experiment!* funding initiative at the German Volkswagen Foundation. First, we investigate rates of submissions for women and men in various science and engineering research areas. Next, we examine, based on a relatively small sample of grant proposals, the distribution of research topics and how men and women contributed to them.

2. Data and methods

2.1 Sample

Scientists from a broad range of research fields sent a total of 2,304 grant proposals to the funding initiative *Experiment!* of the German Volkswagen Foundation between 2013 and 2016.[1] As a major funding organization for science, the foundation issued the program to support exceptional research ideas and unconventional approaches in physical science, life science, and engineering science. In addition, to focus in the selection of proposal on ideas, all information about applicants were concealed in the review process. At the same time, program officers observed unbalanced gender proportions regarding rate of submission as well as rate of success. The ratio between male and female scientists for submissions was 1:2.7 and for granted proposals 1:5.1 (see Appendix A). To understand these rates and to improve the funding process, investigations were started in cooperation with the Volkswagen Foundation to examine research proposals rhetorically, functionally, and structurally in detail. Different research teams mainly applied close reading and in-depth analyses on proposals which provided insights into

concepts of originality (Barlösius, 2019), persuasion strategies (Philipps & Weißenborn, 2019; Barlösius & Klem, 2021), and the use of auxiliaries to qualify propositions. Such approaches, however, are time-consuming and laborious. The Volkswagen Foundation therefore gave access to a restricted number of proposals and allowed us to set up a random sample small enough for close reading and big enough to represent a broad variety of applications covering different research fields, male and female PIs as well as rejected and approved proposals. For this purpose, the sample was randomly selected using more than 300 proposals (simple random strategy). Since one could expect that some applications would not match the formal requirements, it was sensibly decided to work with 350 cases. After excluding proposals with no institutional affiliation and approaches common in humanities or social science, the final sample consisted of 336 grant proposals. This sample hence mainly comprises applications from the research areas physical science and mathematics, life science, and engineering science. However, there are few proposals related to sport science, environmental science, linguistics, and psychology, which are generally embedded in interdisciplinary research with research questions and means designed in the areas of life science and physical science.

One should note that for the present study we had access to metadata of all applications but only to the smaller sample of proposals' full content. Content and topic model analysis were restricted to these 336 accessible applications and thus investigations are more of an explorative character.

Based on these data in this paper, we concentrated on two variables: gender and research areas. Firstly, gender differentiates between female and male applicants who officially submitted a grant proposal. The funding initiative *Experiment!* only allows one principal investigator (PI), but usually there are several people who are involved in writing proposals. However, we assumed that the submitting researchers made the final adjustments on the proposals concerning consistency and style. The gender status for each PI was self-reported to the Volkswagen

Foundation through their online submission system (allowed only to choose between man and woman). Secondly, the Volkswagen Foundation applies its own classification system for science, which was broken down into branches that had two purposes. The funding initiative is meant to attract researchers from "Natural, Technical and Life Sciences"; however, when submitting a proposal, the foundation asked applicants to indicate their affiliated research field. A close look at these fields revealed a broad range from medicine to mathematics to ethnography and from neuroscience to physics; this does not always fit into the categories of physical science and mathematics, life sciences, and engineering science. Moreover, in the assessment process, in-house staff rejected proposals that either failed to fulfil formal requirements or that clearly pursued research in the humanities and social sciences. We reflected these variations and procedures by selecting categories that differentiated between engineering science, life science, physical science and mathematics, and those of humanities and social sciences. Appendix B provides an overview of grouped research areas and they relate to categories used by the Volkswagen Foundation.

2.2 Method

At first, we applied a descriptive analysis of the submissions by women and men in different research areas. Observed variations between men and women in subfields of research areas were reasons to examine proposals and their research topics. In this study, we used topic modeling, in contrast to Burns et al. (2019) who used institutional structures as indicators for thematic research fields and to Allmendinger and Hinz (2002) who applied a manual content analysis of grant proposals' titles. While Allmendinger and Hinz grouped all titles of the applications into thematic areas in the research field of sociology, we had to deal with a broad variety of research fields covering engineering, life science, as well as physical science and mathematics. It would be laborious to manually cluster all the proposals into distinct research topics. In addition, proposals' headings often offered too little information. In some cases, these

titles were very short and vague such as “Quitting Prozac,” “Spread the Seed,” or “Second Hands Controlled by Two Hands.”

Other approaches use scientific papers to detect thematic structures (Griffiths & Steyvers, 2004; Gläser et al., 2017; Daenekindt & Huisman, 2020; Kozlowski et al., 2020). Such approaches often include analyses of citations, author co-citations, and co-words. Approaches based on scientific papers have the advantage that one can combine bibliographic data with text-analytic methods. Topic modelling provides another technique of topic identification. However, this technique remains a field of methodical challenges regarding validity because there is no reliable way of measuring how close such topic exploration come the “true” thematic structure of research (Gläser et al., 2017; Kozlowski et al., 2020). In most cases, topics are not identified but constructed by researchers who make sense of the data. Taking this constructive nature of such approaches into account, topic modelling allows one to deal with great thematic diversity and with several hundred or more texts. For this reason, we used topic modelling and took some measurements to check the robustness of the identified research topics. The strength of topic modelling was somewhat restricted due to the relatively small sample size. A greater number of proposals would have allowed to increase topic granularity.

Topic modelling represents a method of unsupervised classification of documents, originally introduced by Blei et al. (2003) as Latent Dirichlet Allocation (LDA). This procedure divides documents into different semantic clusters exclusively based on the given data and the set parameters. The theory describes the potential creation process of a document (i.e., the selection of the words occurring in it) with the help of several probability distributions. On the one hand, those are the topic distributions for the specified number of topics. Each of these distributions describes a probability distribution over the whole vocabulary. One can, however, imagine that different domain-specific terms are used in different semantic subject areas. These specific words would then be characterized by a much higher probability in their respective topics.

In addition to these topic distributions across the entire vocabulary, the document distributions represent the basis of the procedure, which describes for each document a probability distribution over the estimated number of topics. The theory states that a document consists of a composite set of topics; this composition is described by document distribution. The exact distributions are then determined in an optimization step by inference procedures, such as Gibbs Sampling, to be able to describe the situation with the given data (i.e., the quantity of documents) in the best possible way. More precisely, the distributions that can explain the most likely creation process of the document set are searched for and represented in topic-specific clusters.

In this study, the metadata of the documents are evaluated in relation to their topic affiliation. The affiliation of a document is given by the topic for which its document distribution indicates the highest probability. Other methods, such as the use of a threshold as a membership limit would lead to the possibility that a document might be included several times in different topics in the analysis, while other documents (with a very broad probability distribution over the topics but a low maximum probability) might not be assigned to a single topic at all and would therefore not be part of the analysis. Document's association to topics based on highest probability also is central for measuring the distribution of women's proposals across topics corresponding to the distribution for men. Using mean values in order to determine whether there is a statistically significant difference in the allocation of the individual topics by men and women, a Welch t-test was carried out for each topic. The baseline hypothesis is that the two groups have identical mean values. This was based on the topic probabilities for both groups: Men and women. A Welch t-test was deployed because, on the one hand, it could not be guaranteed that the variances of the values within the two groups were identical and, on the other hand, the two group sizes were unequally distributed.

The topic models were applied in the text mining infrastructure iLCM (Niekler et al., 2018). The iLCM project pursues the development of an integrated research environment for the

analysis of structured and unstructured data in a "Software as a Service" architecture (SaaS). This research environment identifies the requirements for the successful quantitative evaluation of large amounts of unstructured data using text mining means and methods for the reproducibility of data-driven research designs in the social sciences. Written in R and R-Shiny, the iLCM provides an extensible platform for applying text mining techniques to textual data. In addition to the topic models already mentioned, an extensive parameterizable pre-processing pipeline is also integrated into the tool and was used for the analyses described here. In our study, standard pre-processing methods such as stop word removal, pruning, lower casing, and lemmatization were applied. This resulted in a vocabulary size of 1,575 different words. The topic model specific alpha parameter was set to 0.05 and the beta was estimated based on the data having a topic number of 20 selected.[2] A Gibbs sampler with 300 iterations has been used to determine the optimal topic and document distributions. Since LDA describes a non-deterministic procedure, to ensure that the topic contexts found do not merely reflect random findings, the procedure was carried out several times and very similar result patterns were constantly obtained. In addition, for each topic we checked word lists in relation to applicants' research field and the content of single documents. This procedure reinforces our assumption that the represented topic distributions are robust and mirrors the thematic structure of the applications.

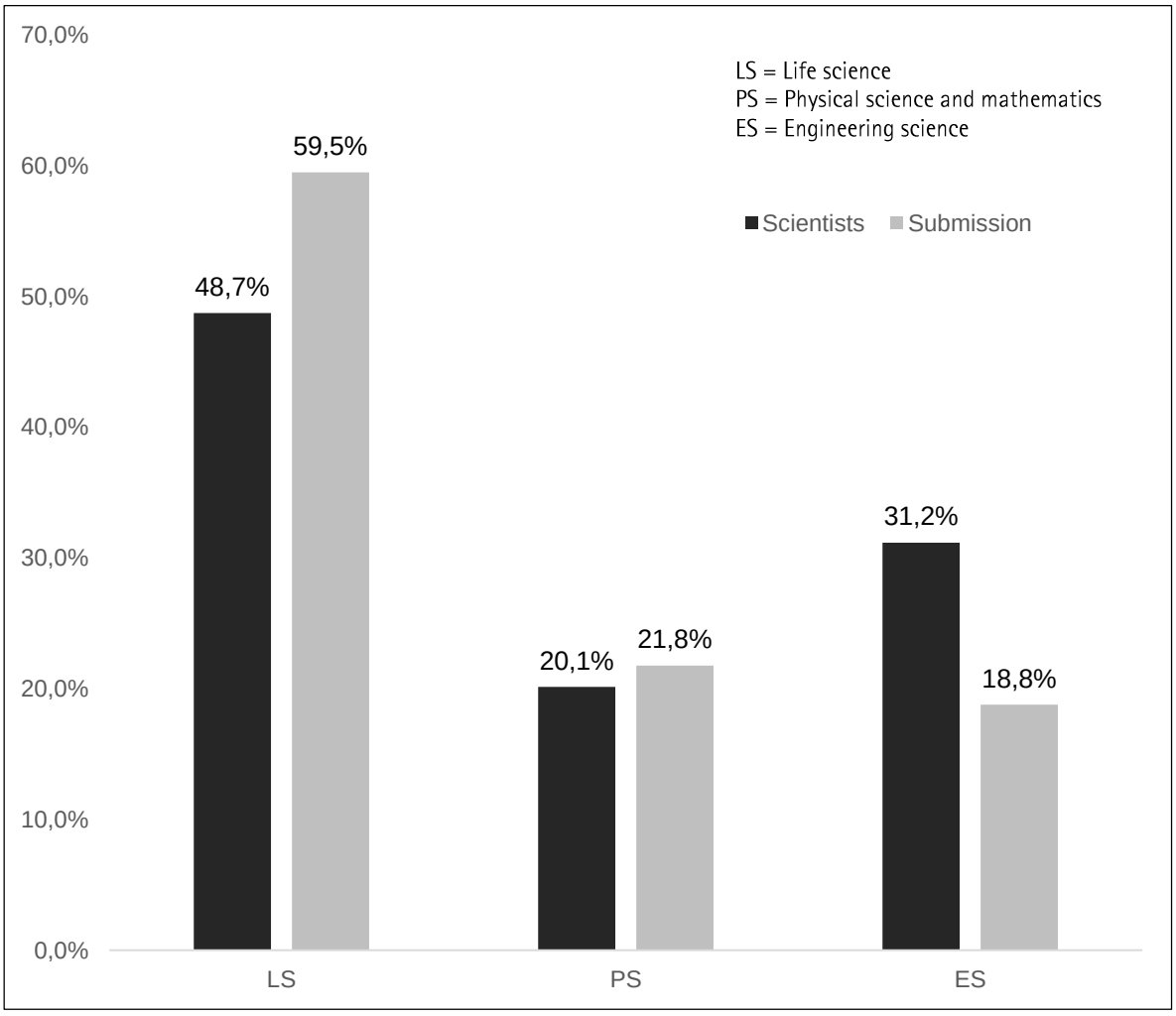
3. Results

3.1 Submission rates

A first glance at the data (see Appendix A) for all 2,304 proposals discloses a surprising finding. Using the DFG classification system, the research funding program *Experiment!* dedicated to "science and engineering, life sciences" (Volkswagen Foundation) also attracts scientists from the research area of humanities and social sciences. This finding might coincide with the exceptional goal of this program as it aims to support unconventional, bold ideas that are clearly

off the track. Funding organizations hardly offer such opportunities, which was especially true for German researchers in humanities and social sciences in 2013. There was almost no program to finance exceptional research without any groundwork. However, these figures need to be differentiated because psychology appears in the DFG classification in social and behavioural science. A close examination of grant proposals reveals that those related to psychology mainly apply physiological and neuronal related approaches, which is closer to life science than social science. Hence, if one takes all 155 proposals related to the research field of psychology from the research area of social science to life science there are 51 applications left in the humanities and social sciences. Interestingly, 41 of the 51 applications were submitted in the first two years, which could be read that researchers in the humanities and social sciences tested the funding opportunity at the beginning. However, it seems to be likely that they turned away when the Volkswagen Foundations introduced a funding program for unconventional research ideas ("Original – isn't it?") for the humanities and cultural sciences in 2014.

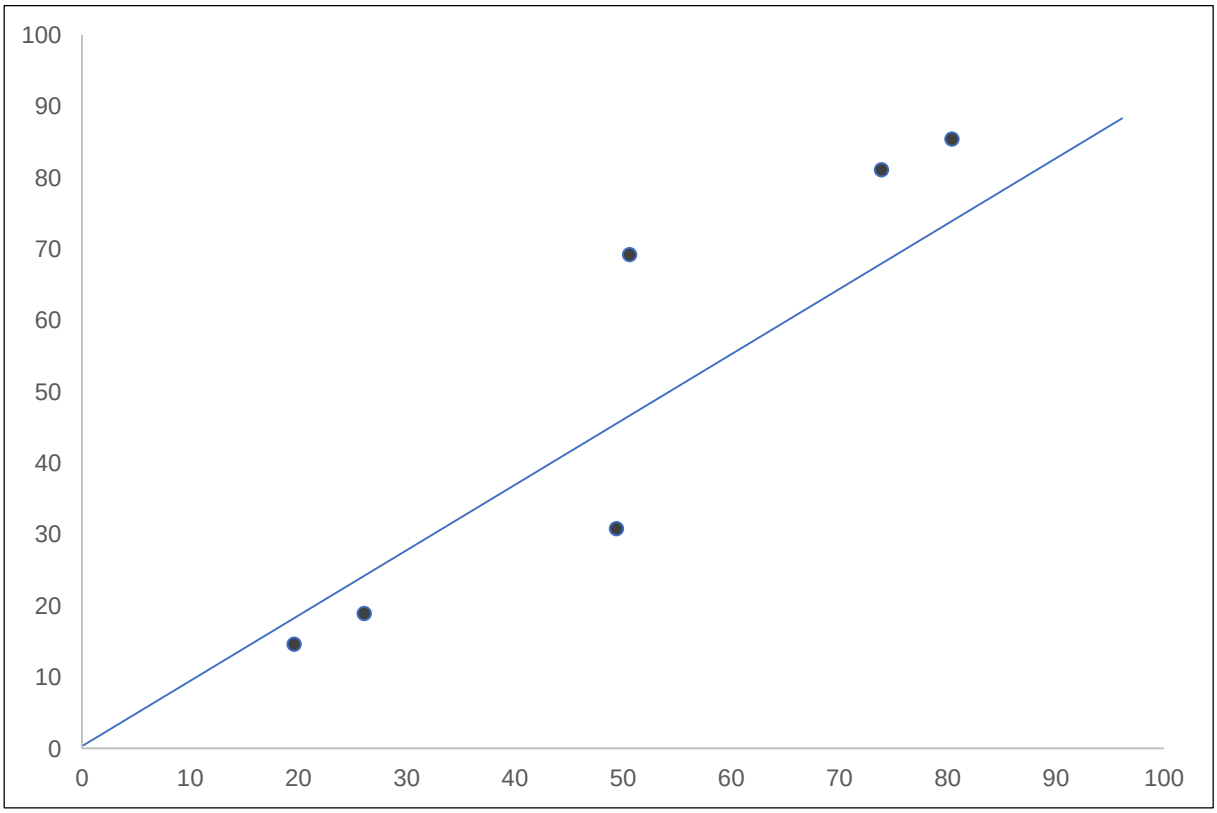
Figure 1 Proportions of scientists in Germany (DFG 2017) and submission rates to the *Experiment!* Grant program



Against this background, if one concentrates on the research areas life science (LS), physical science and mathematics (PS), and engineering science (ES), it becomes evident (see Figure 1) that proportionally most grant proposals in the *Experiment!* funding program came from life science (n = 1,214; 59.5%) whereas life scientists constituted 48.7% (n = 81,598) of all researchers in the sciences (including life science, engineering science, physical science and mathematics) in Germany (see DFG, 2017 and Appendix A). Hence, more life science researchers submitted research ideas but fewer did so in engineering science. The latter comprised 31.2% (n = 52,178) of all researchers in the three research areas but only 18.8% of all applicants (n = 383) had an engineering background. Relatively balanced was the area of physical science and mathematics: 33,721 physical scientists composed 20.1% of the researchers in Germany, and 21.7% (n = 444) applied for grant proposals.

As life science dominates all submitted grant proposals in this funding program, submissions were not evenly distributed between women and men. The greater share of applications sent by life scientists does not correspond with the proportion of female life researchers who submitted grant proposals. According to Figure 2, the number of male and female life scientists in Germany is relatively at parity, but women only submitted 30.8% of all applications in life science. This sharp disproportion is less in engineering sciences and in physical science and mathematics. However, even in these research areas, proportionally fewer women compared to men ask for funding.

Figure 2 Percentages of *Experiment!* —submission rates and proportion of scientists in Germany (DFG 2017)



Further analyses of subfields show (see Figure 3a) that a relatively small number of life scientists in the research field of biology (12.8%) contributed 42.1% of all grant proposals, whereas researchers in the fields of medicine as well as agronomics, forestry, and veterinary science send proportionally fewer applications. However, as Figure 3b reveals, women are more or less at parity in all these research fields, but they submitted more than half of all proposals in agronomics, forestry, and veterinary science and only around one third in biology and medicine. Why does the proportion of proposals vary between research fields? The question is more tempting if one also consults submission rates and proportions of women in research fields of physical science and mathematics as well as engineering science. Figures 3c-f disclose a similar pattern. In certain research fields, researchers sent proportionally more proposals compared to the relative number of scientists in these fields, whereas women did not submit applications at the same rate. In physical science and mathematics (Figure 3c), researchers in chemistry and physics frequently sent more applications, whereas scientists affiliated with

mathematics sent fewer. However, in the latter research field, women's share of applications exceeds their proportion in mathematics (see Figure 3d). The same can be observed for engineering science. A smaller group of researchers in the field of production engineering (40.8%) sent more grant proposals (76.0%) in contrast to the larger group of researchers in informatics, system and electrical engineering. However, in the latter group 17.1% of the women submitted 19.3% of all applications in this research field. In the research fields of civil engineering and architecture by contrast women only applied one proposal during the observed time period.

Interestingly, there is no clear correlation between rates of submission and the proportion of women in the investigated research fields. The submission rate does not increase with more female scientists in a research field or the opposite. We asked ourselves why do women proportionally submitted more proposals in certain research fields and not in others.

Figure 3 Proportion of scientists in Germany (DFG 2017) and submission rates of the *Experiment!* funding initiative (based on DFG classification)

Figure 3a Proportion of scientists and submission rates in the research fields of life science (χ^2 = 905.16 > 5.99, df 2 at 0.05)

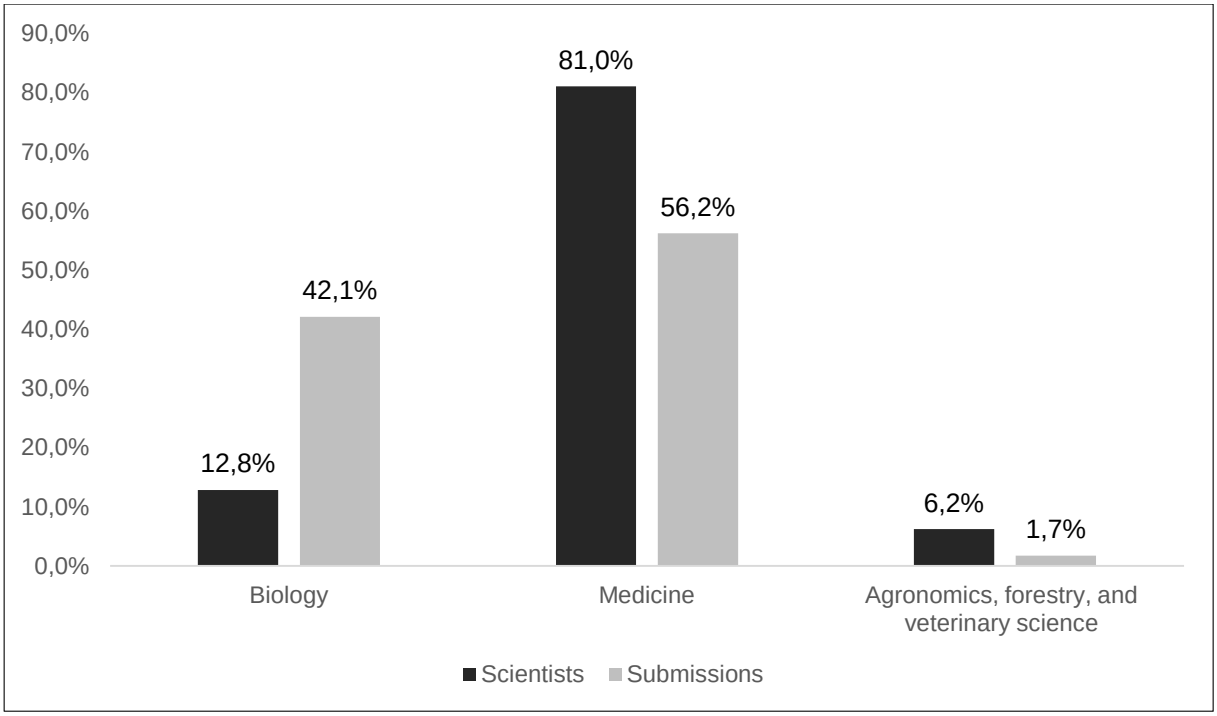


Figure 3b Proportion of female researchers and women's submission rates in the research fields of life science (χ^2 = 951.62 > 12.59, df 6 at 0.05)

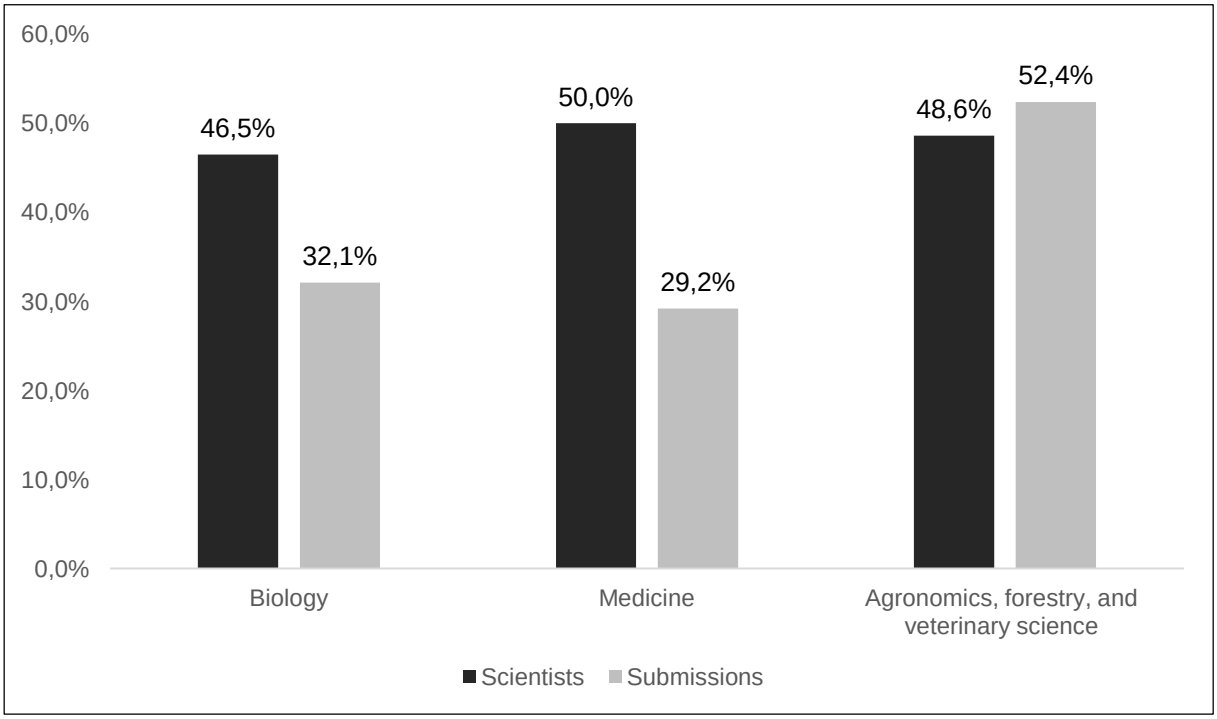
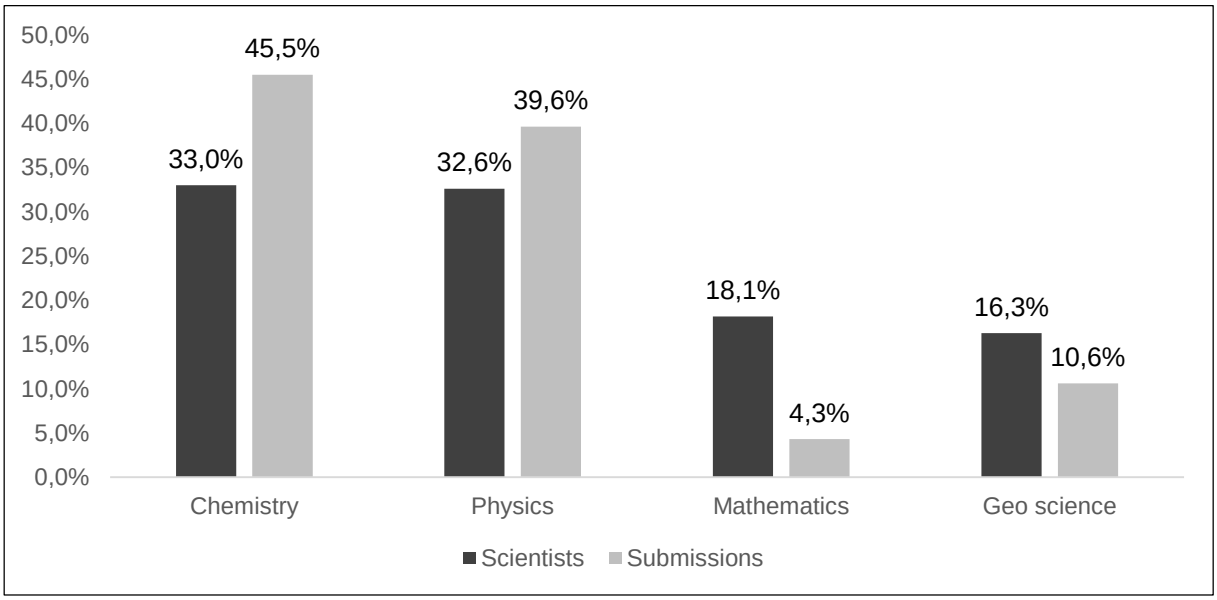


Figure 3c Proportion of scientists and submission rates in the research fields of physical science and mathematics ($\chi^2 = 74.19 > 7.81$, df 3 at 0.05)



3d Proportion of female researchers and women's submission rates in the research fields of physical science and mathematics ($\chi^2 = 791.29 > 12.59$, df 6 at 0.05)

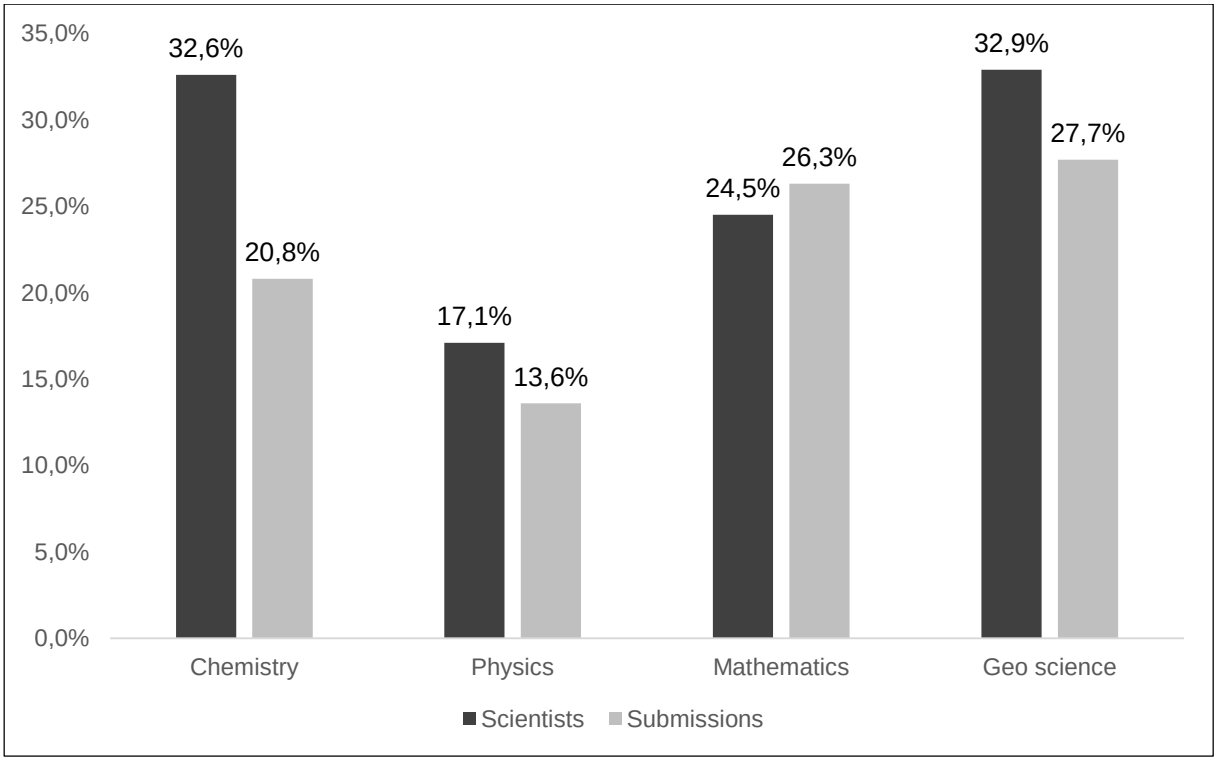


Figure 3e Proportion of scientists and submission rates in the research fields of engineering science (χ^2 = 200.87 > 5.99, df 2 at 0.05)

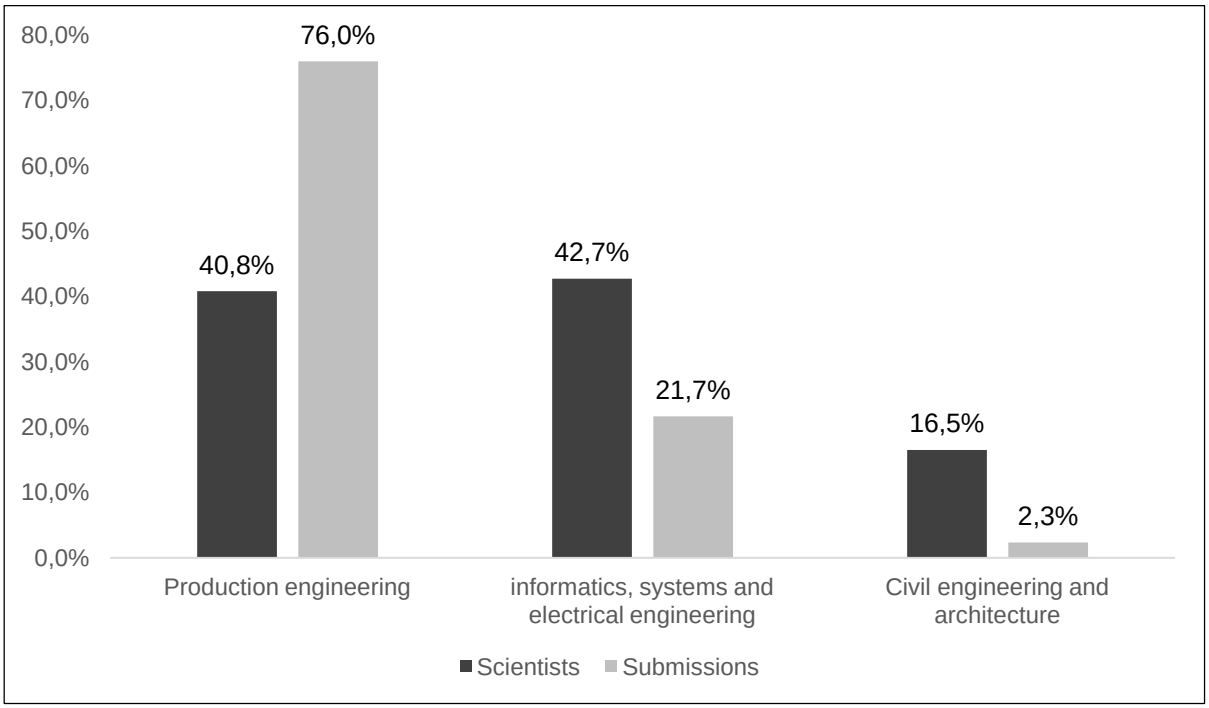
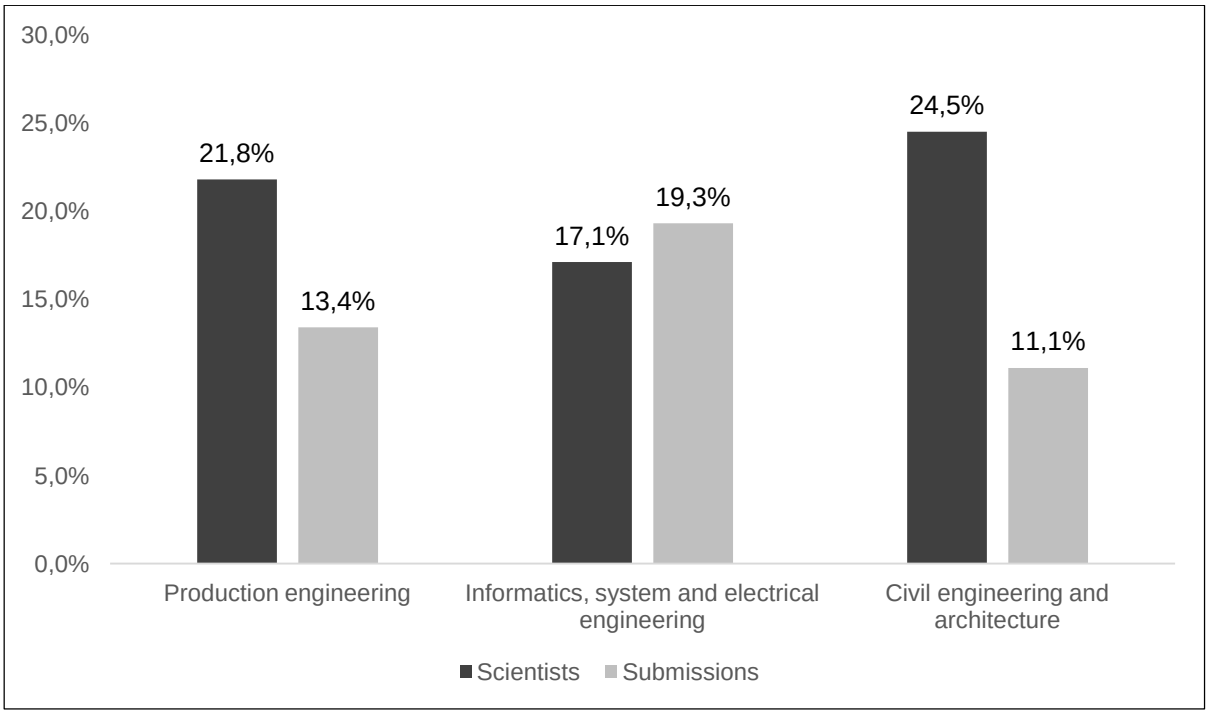


Figure 3f Proportion of female researchers and women's submission rates in the research fields of engineering science (χ^2 test not applicable)



In the case in point, the Volkswagen Foundation's funding program *Experiment!* provides only limited resources (€120,000 for 18 months) to less than 5% of all applicants. One cannot say it is an attractive program for women in mathematics, agronomics, forestry, veterinary science, informatics, system and electrical engineering or for any other scientists to finance incremental research. Against this background, we assume its attractiveness coincides rather with its aim of supporting unconventional approaches. It offers an opportunity to pursue research ideas outside of "normal science" (Kuhn) and to prepare the ground for further investigations. Hence, if the funding program is most attractive to researchers who think beyond existing theories, concepts, and methods, we propose that submissions represent scientifically contentious topics in research fields. Research topics of the funding program *Experiment!* might tell us about researchers' lines of interests and what they view as scientific frontiers. In this regard, we approached our sample of proposals using a topic model to identify and learn about research topics. In our exploration, we determine the relative proportion of contributing women and men for all research topics. One premise was that a relative balanced distribution of female and male applicants indicates a research topic of similar levels of interest for both groups. An unbalanced distribution in contrast is understood as a gendered topic if the relative number of female or male contributors to a topic differs significantly.

3.2 Gendered research topics

In Figure 4, the intertopic distance map (based on a principal component analysis) shows 20 relatively distinct research topics. There are some topics on the left side of the first dimension (PC1), which differ strongly from topics on the right side. Further thematic differences occur along the second dimension (PC2).

Figure 4 Topic model of 336 *Experiment!* grant proposals
Visualization is based on a principal component analysis (PCA). In a topic model, topics are represented by the entire set of different words in the corpus, which therefore also specifies the number of dimensions. PCA is then used to visually represent this very high-dimensional space. The two Principal Components are used to describe the maximum variance of the data. Finally, this allows the mapping of the individual topics into a two-dimensional space that is best able to represent the differences in the topics.

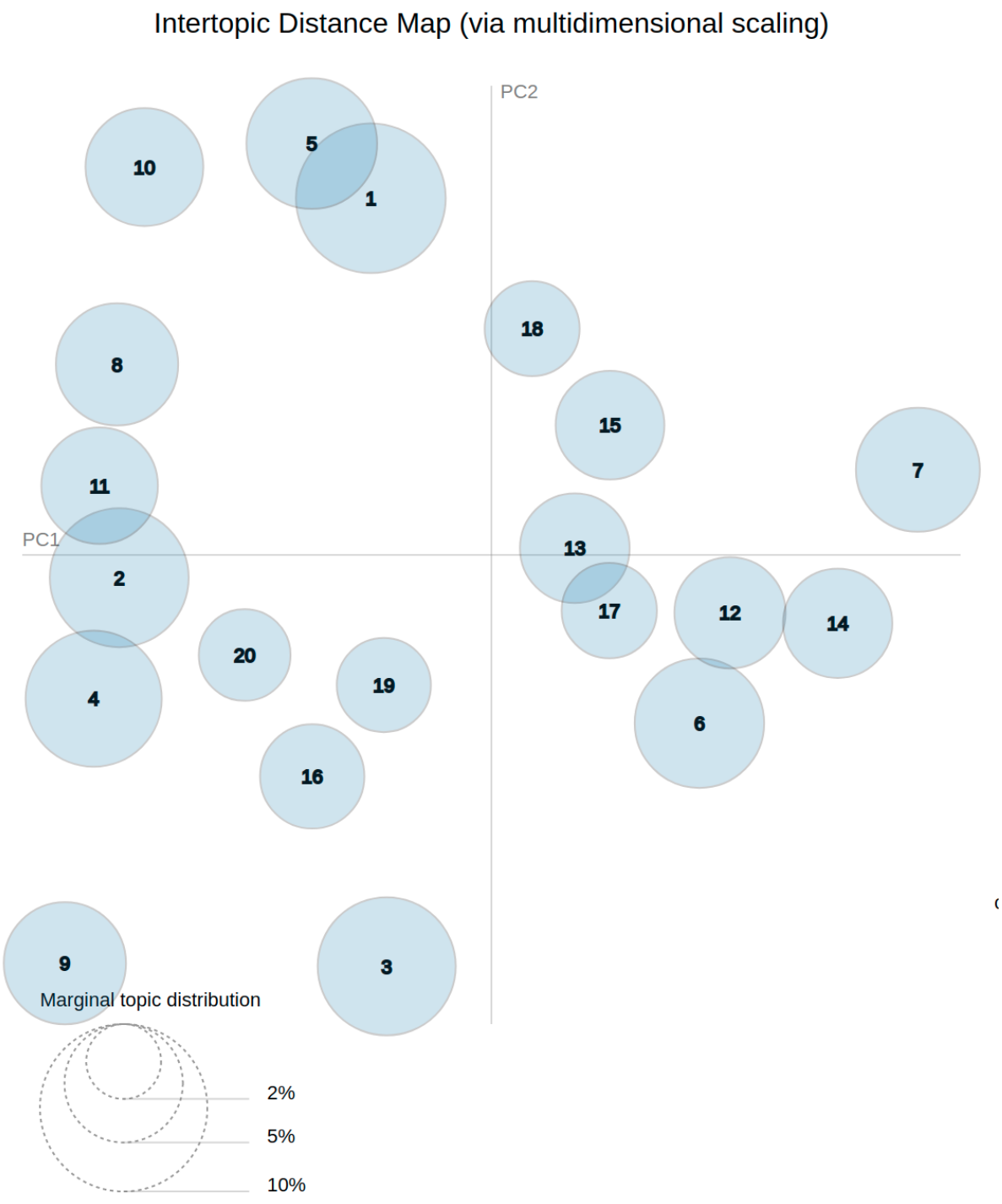


Table 1. Research topics with the five most salient content words, proportions of female and male contributors, and their primary affiliated research field

Topic	Content words	Primary subfields (≥ 50%)
1	child student teacher personality health	Biology, Medicine
2	ray pulse laser imaging light	Physics, Engineering
3	nanoparticle ligand compound reaction precursor	Chemistry
4	polymer production manufacturing printing layer	Engineering
5	speech recommendation fmri language motor	Medicine, Psychology
6	mutant antibody vesicle rna fly	Biology
7	mouse macrophage inflammation degeneration fibroblast	Medicine
8	graph dynamic traffic algorithm theory	Informatics, Psychology, Biology
9	energy quantum proton heat pump	Physics, Chemistry
10	body camera movement object motion	Psychology, Informatics
11	sensor satellite hazard instrument sensing	Engineering, Geo science
12	infection host bacteria parasite pathogen	Biology, Medicine
13	blood vessel skin glucose exposure	Medicine
14	tumor cancer tumour lung leukemia	Medicine
15	reproduction male heterogeneity sex population	Biology
16	methane microbiome ecosystem ocean climate	Biology, Geo science
17	bone graft collagen scaffold cartilage	Engineering, Medicine
18	neuron memory propagation channel synapsis	Medicine
19	plant seed algae rhythm sleep	Biology
20	loading separation deformation engine ring	Engineering, Geo science

Table 1 gives an overview of the research topics and, for each topic five relevant content words (nouns). These terms are not the most frequent words used in each topic but the most salient ones (see Sievert and Shirley 2014). The relevance metric is set at $\lambda = 0.25$ showing terms that mainly appear only in the particular topic. Regarding positions on the distance map (Figure 4) and the content word lists in Table 1, we interpret the topics as following: while research topics 2, 4, 11, and 8 on the far left are concerned with technical aspects, topics 7, 14 and 12 on the far-right focus on medical and health issues. First, this reading is based on salient words such as *laser*, *production*, *manufacturing*, *algorithms*, *instruments*, and many others of the topics on the far left, which are typically technical terms. In contrast, on the far-right we encounter words commonly used in medicine such as *macrophage*, *inflammation*, *infection*, *cancer*, *tumor*, and others. Secondly, applicants with an engineering background mainly contribute to topics on the far left and those trained in medicine and biomedicine to topics on the far-right. Thirdly, if one returns to the grant proposals themselves, close readings also support the thematic interpretation of identified topics. On the left side topic 8, for instance, consists of applications such as Doc ID274 in the field of information technology. The research direction of the proposed project is algorithm engineering. The project aims to design and implement efficient approximation algorithms for real-world scheduling problems. In contrast, Doc ID146 (associated with topic 11) is carried out by an interdisciplinary workgroup, covering the fields of geology, geography, geophysics, robotics, computer science, and telematics. The team proposes to build an on-site sensor technology, which will be able to communicate more effectively. Thematically distinct approaches occur on the far-right side: The proposed project in Doc ID164 (topic 7), for example, is in the field of biomedicine and molecular biology. To further investigate cellular and molecular elements initiating a particular bodily disfunction, different in vitro, ex vivo, and in vivo experiments will be conducted. The aim is to demonstrate the contribution of certain macrophages in the development of specific disorders. The medical and health focus is also evident in Doc ID49 (topic 14), which is in the field of oncology and applies methods from the

field of biochemistry. The aim is to establish novel bio-therapeutically perspectives and to develop new treatment options for cancer and regenerative diseases.

In general, one can say that research topics on the right-hand side are specific, in that they all take rather biological and medical approaches to explore sexual reproduction (15), various facets of organisms (6, 13, 17), or the constitution of memory on the neuronal level (18). This reading is supported by typical word frequencies of and contributions from certain research fields to the above-mentioned topics as well as close readings of grant proposals constituting these topics.

A different thematic cluster of psychological and behavioural approaches occurs in the upper part of the map. It covers topics investigating and observing behaviour (5, 10). Typically used words are *body*, *movement*, or *speech*, and researchers mainly affiliated with psychology and neuroscience contribute to these topics. A related document, such as Doc ID248 (topic 5), states that the project idea is in the field of cognitive psychology and neuroscience. The applicants plan a study with a certain of group of participants to identify the role of feedback in motor control and to extend current concepts of psychomotor learning. In Topic 10 the research idea described in Doc ID40 informs that the study is carried out by a transdisciplinary team of engineers and psychologists. The aim is to identify body language features of people by collecting a certain type of data. Psychological research about body language will build the basis for the design and the set-up of the trials as well as the analyses afterwards. The engineers on the team are responsible for the technical components of the trials as well as the new algorithms for motion detection.

At the lower end, in contrast, research topic 3 is concerned chemically with organic compounds and topic 9 chemo-physically with energy. These topics include salient words such as *compound*, *ligand*, *reaction*, or *energy*, which are associated with chemistry, and these topics have contributors mainly from chemistry and physics. A typical proposal of topic 3 is Doc ID268 located in the field of biochemistry. To create specific enzymes, the applicants intend to

perform a certain strategy of the traditional pathway of enzyme production by putting ligands in a different way. In contrast, Doc ID236 (topic 9) is in the field of chemistry. Experiments will be conducted, which use a certain type of device to create a novel approach and consequently aim to facilitate the transition from conventional energy supplies toward renewable sources.

Finally, other research topics on the lower left side are concerned with engineering aspects (20), plant biology (19) and biochemical aspects of ecosystems (16). In total the topic model reveals a broad variation of research themes from investigations of physical and chemical qualities to studies of technical properties or organic characteristics as well as tests of potentially technical and medical advancements.

In the next step, we calculated the mean distributions of women's and men's contributions across topics. Figure 5 (see last page) reveals that some distributions vary for each topic from relatively balanced to clear differences. They differ statistically significant for the topics 1 to 4 as well as 8 and 9. Topic 1 is clearly dominated by female applicants and topics 2, 3, 4, 8, and 9 by male contributors. Findings, thus, indicate that male scientists are almost exclusively concerned with technical, physical, and chemical subjects. Women in contrast are overrepresented in research on young people's health. Moreover, results also suggest that men and women tend to dominate other specific research topics. Men contributed more proposals, for example, to topic 10 and 18 compared to female contributors, who exceed their male counterparts in topic 7 and 14 to 17.

Comparing these research themes, it is apparent that male scientists concentrate on technical and physical issues but also on neurons (topic 18). Women in contrast mainly research biological and health issues, including studies of tumours and cancer (topic 14), investigations on the reproduction of populations (topic 15) and regeneration of bones (topic 16), as well as analyses of ecosystems and climate (topic 17). These latter tendencies, of course, are not statistically significant. But if one takes into account the relatively small sample size, tendencies

might be proven in a greater pool of proposals. However, such tendencies might also disappear with a greater share of female applicants.

4. Discussion and outlook

The study investigated submission rates and research topics of *Experiment!* grants of the German Volkswagen Foundation. Numbers of grant proposals and distinct research topics were examined in relation to research areas, subfields, and gender proportions. The results indicate that women's and men's contributions vary regarding the relative number of submissions and research topics across the observed research areas.

First, female researchers submit fewer grant proposals. Regarding the funding initiative, one might therefore argue that women have fewer unconventional or radical research ideas. However, there is no straight answer to it because sending a proposal to this program is not a robust sign of having an exceptional idea. Philipps and Weißenborn (2019), for instance, found that only a small proportion of proposals to this program related to neuroscience rhetorically presented scientific ideas in a radical way. It rather seems to be more common that applicants present research proposals aiming to prove concepts and expand previous research and theories. Such ambiguities hence make it difficult to search for gender differences based on exceptionality.

The fact that there were lower numbers of female applicants might have other causes. Various scholars assume that less awareness of funding opportunities or time for research translates into fewer grant submissions. In fact, women are more likely than men to be instructors or lecturers and concerned with service duties—especially in research fields such as biomedicine, pharmacy, or heat and process engineering (Fox et al., 2017; Guarino & Borden, 2017; O'Meara et al., 2019; Rissler et al., 2020). For the funding program, one would expect that women in these or in other research areas with a greater share of practitioners (i.e., medicine, civil engineering, and architecture) submit proportionally fewer proposals. However, a close

investigation of proportions in different subfields shows that women in more service-oriented fields do not necessarily ask for funding less often. Findings for the *Experiment!* funding program rather indicate that women in certain (service-oriented) subfields (i.e., agronomics, forestry, veterinary science) are more active regarding proposal writing than in others. In turn, one can suggest that service duties on their own do not necessarily impede research activities.

Second, taking our preliminary findings constructed with an LDA-based topic model for proposals of the Volkswagen Foundation, it seems that male applicants contribute to all research topics and additionally more often to physical and technical domains. On the other hand, female applicants in this program dominate research on young people's health and assumingly write proposals mostly concerned with biological, health, and medical research topics. Only few of them focus on physical and technical issues. If one takes into account that the grant program is dedicated to finance bold research ideas one could say, in the sample women are forerunners in a relatively narrow spectrum of research topics concerned with biological (ecological) and health issues whereas men dominate physical and technical topics.

The low funding rate of *Experiment!* grants (3–4%) and the small number of successful proposals in our random sample (n = 11) restrict any suggestions about success rates. However, just to give an impression, we might take a closer look at identified research topics and applications that received funding. It appears that financial support went to four research topics (6, 10, 12, 19, 20) covering medical and technical issues with relatively balanced gender proportions. Further granted proposals are found in two research topics (9 on physical matter and 18 on neurons) dominated by men and in topic 17 on ecosystems and climate with a greater proportion of women. In this respect, one could say women's concentration on ecological, biological, health, and medical research is timely and clearly within the scope of funded research topics.

These findings are in line with previous studies on gendered research topics (Allmendinger & Hinz, 2002; Key & Sumner, 2019; Burns et al., 2019). Burns et al. (2019), for example, reported

that the number of grant applications submitted by women was consistently low and that those who directed grants to four health-related institutes focusing on cancer research, circulatory and respiratory health, health services and policy research, and musculoskeletal health and arthritis were significantly less likely to be funded than men. Additionally, Allmendinger and Hinz (2002) showed that female sociologists' concentration on a particular topic caused a decreased success rate. Their investigation of grant proposals in the research field of sociology at the DFG revealed that almost half of all applications submitted by women could be categorized as gender-oriented research. The narrow spectrum increased competition in this topic and had, as well as academic positions such as full professors and academic organization, an impact on the funding outcomes. Compared to men, women were 11.7% less successful. Our findings, of course, allow no prediction about success rates.

A greater pool of proposals would change predictability because it will increase topic granularity and allow studies about changes over time. A higher granularity enables social scientists to differentiate more distinct research themes as well as schools of theories and methods. These topics could then be correlated with gender, type of research institutions, academic status, and so on. Such approaches are informative because one can assume, for example, that research themes vary with the kind of research institution. In particular research universities and other research centres pursue specific research agendas (Atkinson & Blanpied, 2008; Philipps, 2013). The academic status in contrast might correspond with the degree of specialization (Leahey et al., 2008) and thus affect researchers' foci over time. Based on findings that specialization increase productivity one could also assume that it boosts scientists' ability to write persuasive proposals. They then might have better chances in programmatic and research field-specific funding. A concentration on certain research in contrast could also lower chances if proposals are submitted to thematically and disciplinary broad funding programs (e.g., *Experiment!* grants). Future research with greater corpora has to show and deepen our

understanding how the sort of institutions, academic positions, success rate, and other factors influence changes and variations of research topics.

However, our initial findings about the initiative *Experiment!* and results of two other funding bodies in Canada and Germany for different research fields suggest further research on women's choice of research topics and how it translates into the number of submissions and funding success. It includes additional investigations at other funding organizations for the same and different research areas and fields. There is evidence that women more likely than men take care of teaching and service duties (Fox et al., 2017; Guarino & Borden, 2017; Rissler et al., 2020) and that female scientists produce fewer publications (Xie & Shauman, 2003; Abramo et al., 2009; Lariviere et al., 2011; Huang et al., 2020), but we hardly know how women's research foci affect their scientific contributions, chances, and careers as a whole. Moreover, it also requires further thoughts on methodology. Manual coding or unsupervised automatic clustering of research topics have their limitations. Trained annotators might be more equipped to demarcate and identify research topics. However, they reach their limits coding hundreds or thousands of documents. Automatic text mining on the contrary enables researchers to cluster large samples of textual data, but this method still lacks robust measures to validate outcomes (Gläser et al., 2017). Future research will need to find answers to solve problems of topic recognition. In this study we first calculated multiple topic models to check for reoccurring patterns in word cooccurrences. Secondly, we considered word lists and applicants' research field and read single documents associated with a topic to provide a relatively robust understanding of constructed research topics. However, using a random sample could not represent all research topics in the grant proposals in a very differentiated way. In particular, the low number of grant applications from mathematics, agronomics and forestry, or informatics inhibited investigations on how women and men contributed to these research fields.

Nevertheless, if further studies provide evidence for gendered research topics, funding policies that are intended to increase the proportion of women in science and engineering fields might be changed by introducing new programs dedicated to research topics that better match women's research foci. In the social sciences, as reported by Almendinger and Hinz (2002), implementing a funding program on gender studies, for example, leads to more submitted grant proposals by women than in other programs.

Notes

1 See URL: https://www.volkswagenstiftung.de/en/funding/our-funding-portfolio-at-a-glance/experiment (last accessed December 18, 2020).

2 The specific number of topics was selected after merging and splitting 40 topics with the TopicExplorer (Papilloud and Hinneburg 2018). This tool allows researchers to decrease the number of topics and check for the topics' specificity and interpretability in small steps.

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Appendix A

Research areas and fields (DFG)	Scientists in Germany			Applicants (all)		
	Total	Women		Total	Women	
		Total	Percent		Total	Percent
Humanities and social sciences	**71.703**	**32.964**	**46.0%**	**206**	**85**	**41.3%**
Humanities	28.102	13.676	48.7%	14	9	64.3%
Social and behavioral science	43.601	19.288	44.2%	192	76	39.6%
Life science	**81.598**	**40.342**	**49.4%**	**1.214**	**374**	**30.8%**
Biology	10.451	4.862	46.5%	511	164	32.1%
Medicine	66.107	33.032	50.0%	682	199	29.2%
Agronomics, forestry, and veterinary science	5.040	2.449	48.6%	21	11	52.4%
Physical science and mathematics	**33.721**	**8.815**	**26.1%**	**444**	**84**	**18.9%**
Chemistry	11.123	3.628	32.6%	202	42	20.8%
Physics	10.996	1.881	17.1%	176	24	13.6%
Mathematics	6.117	1.500	24.5%	19	5	26.3%
Geo science	5.484	1.806	32.9%	47	13	27.7%
Engineering science	**52.178**	**10.217**	**19.6%**	**383**	**56**	**14.6%**
Machine and production engineering	13.908	2.487	17.9%			
heat and process engineering	4.708	1.134	24.1%	291	39	13.4%
material engineering	2.660	620	23.3%			
informatics, systems, and electrical engineering	22.282	3.242	14.5%	83	16	19.3%
Civil engineering and architecture	8.620	2.734	31.7%	9	1	11.1%
Total	**239.200**	**92.338**	**38.6%**	**2.247**	**599**	**26.7%**
Sports science				20	3	15.0%
Environmental science				33	15	45.5%
No indication				4	2	50.0%
Total				**2.304**	**619**	**26.9%**

Source:

1) Chancengleichheits-Monitor DFG (2017): Statistisches Bundesamt (DESTATIS): Bildung und Kultur. Personal an Hochschulen 2015. Sonderauswertung zur Fachserie 11, Reihe 4.4. Calculation by DFG.
2) Figures about the funding program *Experiment!* of the Volkswagen Foundation. Own calculations.

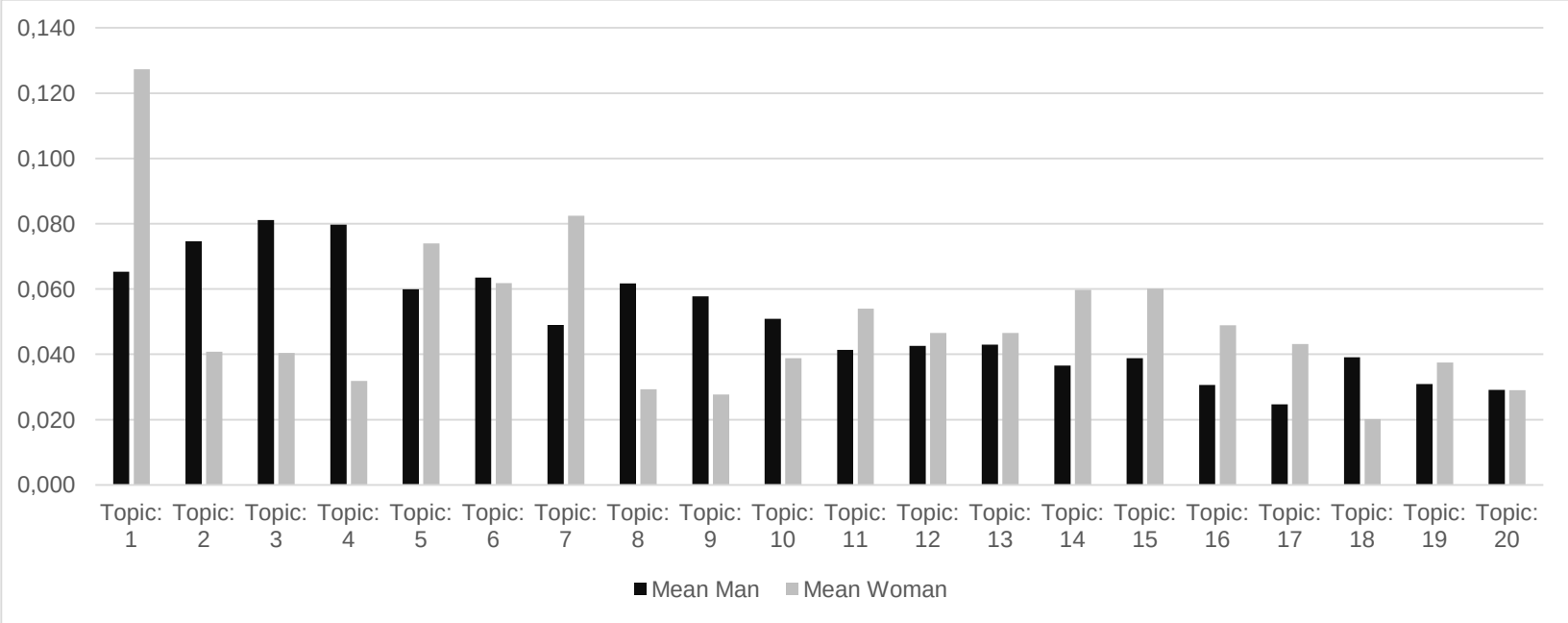
Appendix B

Categories according to …		
DFG's research areas	**DFG's subfields**	**Volkswagen Foundation**
Engineering science	Civil engineering and architecture	Architecture
	Machine and production engineering, heat and processing engineering, material engineering	Engineering
	Informatics, systems, and electrical engineering	Informatics
Life science	Agronomics, forestry, and veterinary science	Agriculture and forestry
		Veterinary medicine
	Biology	Biochemistry/Biophysics
		Biology
	Medicine	Biomedicine
		Health science
		Medicine
		Neuroscience
		Linguistics*
		Pharmacy*
		Psychology*
		Sport science*
Physical science & mathematics		Environmental science
	Chemistry	Chemistry
	Mathematics	Mathematics
	Physics	Physics
	Geo science	Geography
		Geoscience
Humanities & social science		Archeology, Communication & media science, Cultural studies, Economics, Educational science, Ethnography, History, Literary studies, Philosophy, Political science, Science of management, Sociology
Unclear		No indication

Note: Categories are used throughout the paper from left to right, from research areas (DFG) to subfields (DFG) to categories of the Volkswagen Foundation.

* All grant proposals in the sample from applicants who affiliated themselves with linguistics, pharmacy, psychology, and sport science pursued physiological and/or neuroscience approaches.

Figure 5 Mean distribution of men and women across research topics



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mean Man	0,065	0,075	0,081	0,080	0,060	0,063	0,049	0,062	0,058	0,051	0,041	0,043	0,043	0,037	0,039	0,031	0,025	0,039	0,031	0,029
Mean Woman	0,127	0,041	0,040	0,032	0,074	0,062	0,082	0,029	0,028	0,039	0,054	0,047	0,047	0,060	0,060	0,049	0,043	0,020	0,037	0,029
Difference	0,062	0,034	0,041	0,048	0,014	0,002	0,033	0,032	0,030	0,012	0,013	0,004	0,004	0,023	0,021	0,018	0,018	0,019	0,007	0,000
SD Man	0,183	0,164	0,183	0,182	0,166	0,160	0,158	0,157	0,160	0,148	0,122	0,125	0,127	0,136	0,118	0,113	0,104	0,132	0,110	0,095
SD Woman	0,258	0,125	0,099	0,112	0,177	0,143	0,196	0,100	0,087	0,106	0,160	0,138	0,112	0,162	0,147	0,146	0,155	0,070	0,127	0,117
p-value	0,029	0,039	0,009	0,003	0,495	0,925	0,128	0,024	0,027	0,400	0,477	0,803	0,793	0,207	0,194	0,260	0,271	0,089	0,647	0,993