Sex-bias in biomedical research: a bibliometric perspective

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Models of human disease have traditionally been biased towards the male body. Here, we perform a retrospective study of factors that may have contributed to (reducing) this bias across a variety of biomedical topics and study types in the USA during 1987-2009. First, a large-scale bibliographic dataset was constructed based on over 200,000 human sex-specific papers (tagged exclusively as Male or Female, and Human in PubMed) with a US author affiliation. Each paper was scored on over 40 dimensions capturing aspects of authors, institutions, local population demographics, funding, journals, topics, age groups, study types, and time. Several of these attributes were inferred using tools developed in-house (all available from http://abel.lis.illinois.edu): **MapAffil** infers author institution type, geocodes author affiliations, and has links to US Census data, **Author-ity** disambiguates author names which enables calculating authors' professional ages, **Genni** infers authors' genders, and **Ethnea** infers the authors' ethnicities. A temporal logistic regression model was trained to predict the sex-tag of the paper in order to quantify the intrinsic bias associated with each of these predictive attributes. We find that almost all of the scored attributes influence the sex-tag and, for many, this influence has not changed over time. For example, brain-related studies have been and continue to be biased towards males while heart-related studies used to be biased towards males but today are not. Some good news: clinical trials, NIH-funded studies, and papers by authors from commercial organizations used to be strongly biased towards male studies but today are not. This is in part a reflection of working NIH policies, and perhaps a shift in monetary incentives in the pharmaceutical industry. A major concern is that female studies are more likely to be published in lower impact journals, and it has not changed during this period. This journal effect is probably a reflection of persistent sex-biases present in the publication process in general, including peer-review and author/editorial decision making. The journal effect was brought to light due to included confounds like the publication types -- male studies are biased towards Case-Reports and Comments, while female studies are biased towards Reviews. Furthermore, each male (and female) author on a paper had a positive additive effect on the odds of a Male-tag (and a Female-tag, respectively), and this effect has grown over the years. That is, author gender has had a strong polarizing effect on sex-bias and has become even more polarizing over time, counteracting the additive effects of a growing population of female scientists. Perhaps more interestingly, the first-added male author on a paper exhibited a much stronger influence than any female or additional males on a paper. In other words, a sole man among women is more influential and a sole woman among men is less influential, probably reflecting a heightened stereotypical behavior in unbalanced co-authorships. This effect was not due to seniority – the gender of the senior author had no influence although the age of the senior author was positively correlated with a Female-tag (which appeared as a case of Simpson's Paradox). It should be noted that several of the intrinsic biases only came to light because of the multi-dimensional nature of the model – it accounts for a variety of confounds such as publication types and generic topics. This hints at the complexity of the phenomenon under study and implies that simple models (and simple visualizations such as the ones in Figure 1) can be misleading.

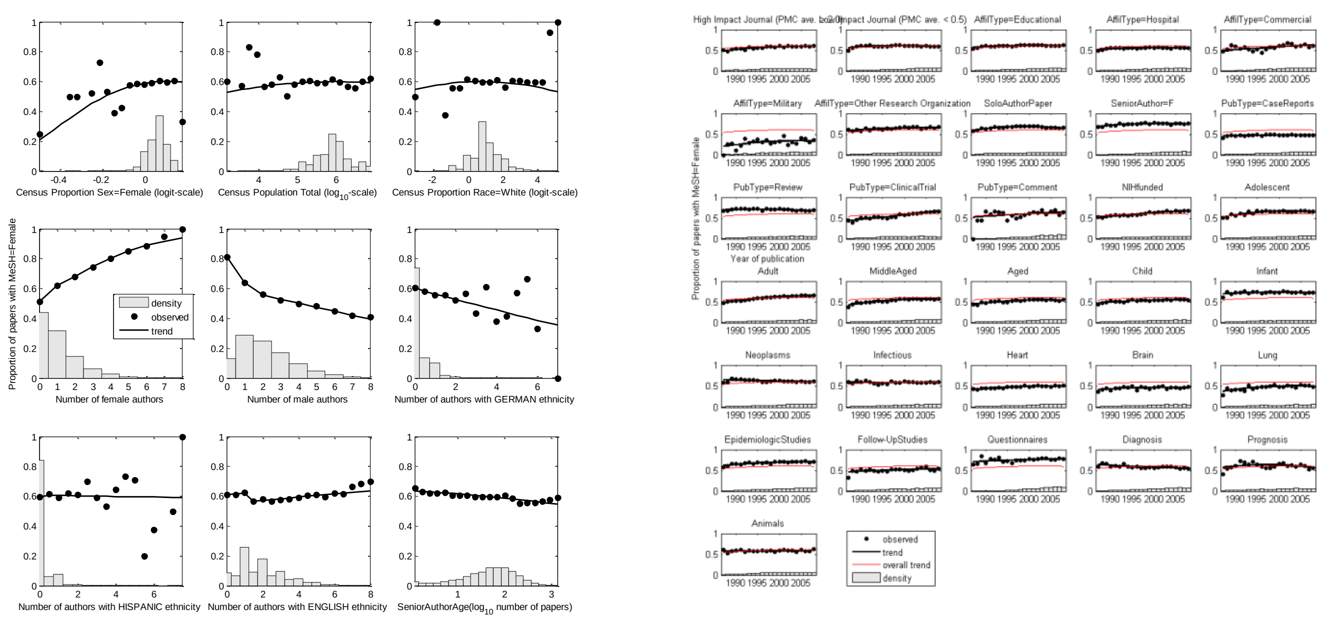

Figure 1. Sex-bias trends of some of the predictive attributes. Note that some of these trends might be weaker or even reversed when considering a multidimensional statistical model due to strong confounding effects. The left figure shows distributions across multi-valued attributes while the right figure shows binary attribute trends over time.