Why Are There So Few Women in Computer Systems Research?

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Numerous explanations have been proposed for the underrepresentation of women in computer science research. Using an expansive dataset, we ask which of these explanations apply even more to researchers in computer systems.

In a recent study, we found that the ratio of female-to-male authors in computer systems conferences is particularly low, even compared to the rest of computer science (CS).[1] The large and statistically significant underrepresentation cannot be fully explained by review bias, differences in collaboration patterns, and numerous other demographic and conference factors alone.[2]

INTRODUCTION

Having previously answered the question of "how many women are in computer systems research?", we now ask "why are there so few women in computer systems research?", expanding beyond measurable facts and venturing into the domain of hypothesis and speculation. This simple question likely has no simple answers, and this article does not attempt to provide any definitive ones either. Instead, we attempt to break down this big question into a number of smaller, speculative questions, and gather what evidence we can find to provide, if not outright answers, at least justification for the questions and for future investigation.

There are many dimensions—economic, societal, historical, and structural—that influence this gender gap.[3,4] We may never be able to explain it fully; however, we can examine many of the factors that have been previously identified as possible contributors to the gender gap in CS and other sciences in an attempt to assess whether they have an outsize effect on systems in particular. (For this study, we define *systems* as the study and engineering of

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concrete computing systems, which includes research topics such as operating systems, computer architectures, data storage and management, compilers, parallel and distributed computing, and computer networks.) Based on our experience in the field, our conversations with fellow female researchers about their experiences, and the existing literature on the gender gap in other fields, we attempt to examine possible contributors to the gender gap in CS and other sciences in the specific context of the systems field.

In this viewpoint, we examine 10 such factors, supporting our discussion with quantitative evidence when possible. Our main source of data is a manually curated dataset of 72 reputable CS conferences, all from 2017. The conferences from the fields we identified as systems included a total of 7,507 unique authors, with the remaining 16,971 unique authors from nonsystems conferences. All 6,949 peer-reviewed research-track papers in these conferences and their authors were included in the data. We manually matched most authors with a perceived gender, based on pronouns and photos, rather than using automated approaches using name-based inference because the accuracy and recall of this inference can be quite low for some populations. In total, we analyzed 27,743 authors (19,761 unique). The complete methodological aspects of identifying and cleaning the appropriate data as well as the main statistical findings about the underrepresentation of women in the field can be found in our original study.[1]

Here, we combine our current dataset with prior studies to try to evaluate the impact of each of the 10 potential factors on the increased gender gap in systems, each presented as a hypothesis that it has a more significant effect on the gender gap in systems in particular. The 10 hypotheses are organized into two groups: six where our data provide evidence for or against an increased effect and four for which we have no specific data but can speculate based on the characteristics of systems research. For each factor, we briefly explain its observed effects on the gender gap from previous studies and then try to find support in the data (or lack thereof) for an increased effect of this factor in systems.

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FACTORS FOR WHICH WE HAVE QUANTITATIVE EVIDENCE

Hypothesis 1: Too few women peers and mentors

Paradoxically, a large gender gap in a field could itself be partially caused by an existing large gender gap. The lack of female mentors, peers, and role models dissuades women from entering or remaining in a field where they can feel unsupported and singled-out.[5,6,7,8,9] Additionally, it appears that women in systems have a small but significant preference to publishing with other women—who are already scarce.[1] This gender homophily is certainly not unique to this field, but it reinforces the notion that having fewer women in systems makes it less inviting to new women.

Moreover, in the overall 6,949 CS papers we looked at, when the senior (last) author is a woman, non-senior authors include 17.5% women, compared to only 9.6% when the senior author is a man. However, of the 2,439 papers in systems, only 9.9% have a female senior author, compared to 14.8% in nonsystems papers. The paucity of systems papers with senior women suggests that junior women have about a 50% better chance to find a senior woman to collaborate with outside of systems.

Hypothesis 2: Highly collaborative fields are less welcoming to gender minorities

Another potential consequence of having fewer peers and fewer publications for women is that finding similar collaborators for a research project may be more difficult in certain fields,[10,11] especially those that typically require larger research teams.[1] So the largely male teams may feel less welcoming to women authors, compared to fields that rely less on large collaborative efforts. Indeed, in our dataset, systems had the largest team sizes (5.08 mean coauthors per paper versus 3.56 in other fields), possibly because this field often requires large collaborative efforts to implement complex systems. (Men also averaged 2% larger team sizes than women, but this difference was not statistically significant.)

Hypothesis 3: Women are better represented in human-centered fields

It has been shown that owing to traditional social roles, women tend to be more people-centered and communally oriented than men in their career choices.[12,13,14] On the other hand, most science and technology careers are not perceived as focusing heavily on these values.[8,9] Even within CS, the representation of women appears much higher in fields ostensibly centered on humans, such as human–computer interaction and computer education (Table 1). Although many computer systems directly and indirectly benefit society, the field could be perceived as one that primarily focuses on machines and not on societal or community benefits. That perception alone may further deter women's entry into the field.

Hypothesis 4: Women are underrepresented in engineering fields

CS is a varied discipline that combines aspects from mathematics, algorithmics, and engineering. In particular, work in systems is very similar to other engineering disciplines, with its emphasis on efficiency, tradeoff management, and practical applications. At least 9% of the systems papers in our dataset have one or more authors affiliated with an academic engineering department, although the percentage of authors with an electrical or computer engineering degree is potentially even higher. It is therefore not surprising that the representation of women we find in systems papers is very similar to some estimates for engineers in general.[15,16]

Hypothesis 5: Fewer women pursue research in industry

Women engineers also appear to be significantly underrepresented in industry research.[17,18] As a field related to engineering, we might expect systems to exhibit similarly large gender gaps for industry researchers. In addition, since systems research and development is increasingly central to the success of both technology startups and large-scale companies such as Google, Amazon, and Microsoft, we might also expect the high demand for skilled workers in industry to amplify this factor.

Despite our expectations, the hypothesis that an industry affiliation leads to a higher gender gap in research is only weakly supported by our data. By extracting the e-mail address associated with each author in our systems papers, we can roughly categorize each author with a uniquely identifiable affiliation as either in government, academia, or industry.[2] Of the 13.9% authors with an industry affiliation, 8.8% were women, not much lower than the overall rate of women.

Hypothesis 6: Women leave research careers at a higher rate than men

It is well known that women in the sciences and CS leave academia at a higher rate than men (the so-called "leaky pipeline").[4,9,15,19] Looking at the ratio of researchers in our dataset who appear to have stopped publishing by 2019, we find, surprisingly, that women did not leave research at a higher rate than their male counterparts; only 16.9% of women ostensibly stopped publishing, compared to 24.4% of men. As another measure of the retention rate of women to senior positions, we can also look at the ratio of female last authors, since in CS and especially in systems, authors are often ordered by contribution, with the senior author at the last position. In our dataset, only 12.3% of systems papers with three or more authors have ordered them alphabetically. Women last authors appear in 9.9% of our systems papers, which is actually closer to the ratio of all female authors in systems, 10.3%, compared to the ratios in nonsystems papers (14.8% and 16.3%, respectively), suggesting a similar or lower attrition rate for women in systems. Rather than having an attrition problem, it is possible that the field has a bigger challenge attracting women to the field in the first place.

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FACTORS FOR WHICH WE HAVE NO QUANTITATIVE EVIDENCE

Hypothesis 7: Systems research requires more precollege programming experience

The gender disparity in precollege computing and programming experience has been studied extensively as a factor affecting postsecondary participation in CS.[5,6] Systems research in particular may require an intimate understanding of programming systems and may benefit from

TABLE 1. The percentage of female authors in peer-reviewed conference papers across fields of CS, omitting authors with ambiguous gender.

Field	Total Authors	Female Authors*
CS education	457	42.2%
Human–computer interaction	4,066	26.3%
Knowledge systems	1,793	16.1%
Software engineering and languages	961	13.7%
Artificial intelligence	8,908	11.8%
Computer systems	9,678	10.3%
Theory and algorithms	1,241	8.3%
Overall	27,104	14.1%

* Authors count multiple times when they appear on more than one paper. The difference in female author ratio between systems and nonsystems fields is statistically significant ($p < 10^{-9}$).

precollege programming experience, as has been found for the systems subfield of high-performance computing.[8] Precollege girls were also found to be less likely than boys to dissect a computer.[12] Since women are less likely to learn about hardware and software at a young age, they may be less experienced than men with the low-level programming tasks required in systems.

Hypothesis 10: Women's participation rate in a field varies by geography

Several studies have found that regional, cultural, and societal factors can significantly affect the number of women in a field.[5] For example, even the geographical variance in implicit gender stereotypes can explain gender disparity in math and science performance.[21] In our dataset, the representation of women varies considerably by country.[2] Even among the top 20 countries (by number of authors), representation varies from 2% in Portugal and Japan to 14% in Sweden (11.4% in the United States, the largest country with 55% of systems authors). We don't have evidence for gender stereotypes or cultural differences that are specific to computer systems, but we could hypothesize that when it comes to systems, some of the preceding hypotheses have the potential to sharpen preexisting cultural biases toward CS and sciences in general, such as the effects on work–life balance.

At an institutional level, one approach may be to hire a cluster of women researchers together instead of piecemeal.

Hypothesis 8: Women are underrepresented in more expensive fields

Studies have shown that in fields where research financial expenditures are higher, women consistently publish less than men.[20] Systems research often requires expensive equipment such as experimental computer architectures, supercomputers, or cloud resources. It is therefore plausible that the higher cost of systems research leads to lower participation and publication rates by women, as opposed to other, less costly CS fields.

Hypothesis 9: Systems research implies worse work–life balance

If systems research is indeed more competitive than some other academic fields (for which we found no published evidence), it may require a bigger commitment to work for success. Similarly, many of the technology companies that attract skilled systems researchers have a reputation for long working hours. These factors could lead to a work–life balance that is worse for systems than it is for some other CS research fields. Some women may already feel that a CS career is hard to reconcile with raising a family,[12] and the perception of systems careers as particularly demanding may exacerbate this problem.

The possible explanations for the gender gap we listed here are by all means not exhaustive. Other well-known factors we didn't discuss include occupational stereotypes, ability, confidence, demographics, discrimination, bias, competitive work, and a sense of belonging or of being valued. We found no specific reasons to believe that these additional factors have an increased effect in systems research. However, we have heard anecdotal complaints from women practitioners about the toxic masculine culture in systems labs and some systems conferences. Read, for example, Margaret Martonosi's statement on diversity in at the MICRO-50 conference in the ACM SIGARCH blog.[23]

Attempting to generalize the 10 specific factors we discussed is challenging because the observed aggregate gender gap is the result of many individual decisions based on individuals' circumstances and experiences. One common thread, however, is the chicken-and-egg nature of the problem. Most of the factors (causes) are themselves exacerbated by the current dearth of women in the field (effect), which has persisted for years. We therefore believe that addressing this chicken-and-egg problem cannot succeed with diversity initiatives in hiring or conferences alone.[2] Such initiatives are clearly welcome, as are other interventions to reducing the gender gap in CS.[6,22] But for systems in particular, we think a concerted effort is warranted to significantly increase the number of women across the field, making it more welcoming to women and minorities in general and bootstrapping a long-term solution.

At an institutional level, one approach may be to hire a cluster of women researchers together instead of piecemeal. Given the existing gender gap we described, this is admittedly easier said than done, but hiring one woman at a time may actually contribute to the problem rather than the solution, as we described. To address this challenge, an institute may take a long-term perspective of encouraging a large group of women to enter the field early in graduate (or even undergraduate) school, offering them a clear career horizon with reasonable prospects of returning as faculty. At a national level, governments and large professional organizations such as IEEE and ACM could commit to long-term scholarships and grants for women in the field, starting perhaps as early as high school and continuing to support them through the formation of a research lab, perhaps all the way to tenure. At both levels, we posit that a sustainable solution requires a large initial investment to reach a critical mass, thus helping to attract and retain future women in systems.

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REFERENCES

1. J. Yamamoto and E. Frachtenberg, "Gender differences in collaboration patterns in computer science," *Publications*, vol. 10, no. 1, p. 10, Feb. 2022, doi: 10.3390/publications10010010.
2. E. Frachtenberg and R. D. Kaner, "Underrepresentation of women in computer systems research," *PLOS One*, vol. 17, no. 4, Apr. 2022, Art. no. e0266439, doi: 10.1371/journal.pone.0266439.
3. B. Avolio, J. Chavez, and C. Vilchez-Roman, "Factors that contribute to the underrepresentation of women in science careers worldwide: A literature review," *Social Psychol. Educ.*, vol. 23, no. 3, pp. 773–794, Apr. 2020, doi: 10.1007/s11218-020-09558-y.
4. R. Singh, N. A. Fouad, M. E. Fitzpatrick, J. P. Liu, K. J. Cappaert, and C. Figuereido, "Stemming the tide: Predicting women engineers' intentions to leave," *J. Vocational Behav.*, vol. 83, no. 3, pp. 281–294, 2013, doi: 10.1016/j.jvb.2013.05.007.
5. S. Cheryan, S. A. Ziegler, A. K. Montoya, and L. Jiang, "Why are some stem fields more gender balanced than others?" *Psychol. Bull.*, vol. 143, no. 1, p. 1, 2017, doi: 10.1037/bul0000052.
6. J. M. Cohoon and W. Aspray, "A critical review of the research on women's participation in postsecondary computing education," in *Women and Information Technology: Research on Underrepresentation*. Cambridge, MA, USA: MIT Press, 2006, ch. 5, pp. 137–180.
7. B. J. Drury, J. O. Siy, and S. Cheryan, "When do female role models benefit women? The importance of differentiating recruitment from retention in STEM," *Psychol. Inquiry*, vol. 22, no. 4, pp. 265–269, 2011, doi: 10.1080/1047840X.2011.620935.
8. A. Frantzana, "Women's representation and experiences in the high performance computing community," Ph.D. dissertation, Univ. Edinburgh, Edinburgh, U.K., 2019.
9. S. Kahn and D. Ginther, "Women and stem," National Bureau of Economic Research, Cambridge, MA, USA, Tech. Rep. w23525, 2017.
10. J. Abbate, *Recoding Gender: Women's Changing Participation in Computing*. Cambridge, MA, USA: MIT Press, 2012.
11. X. H. T. Zeng et al., "Differences in collaboration patterns across discipline, career stage, and gender," *PLOS Biol.*, vol. 14, no. 11, Nov. 2016, Art. no. e1002573, doi: 10.1371/journal.pbio.1002573.
12. S. Beyer, K. Rynes, and S. Haller, "Deterrents to women taking computer science courses," *IEEE Technol. Soc. Mag.*, vol. 23, no. 1, pp. 21–28, Spring 2004, doi: 10.1109/MTAS.2004.1273468.
13. A. B. Diekman, E. S. Weisgram, and A. L. Belanger, "New routes to recruiting and retaining women in stem: Policy implications of a communal goal congruity perspective," *Social Issues Policy Rev.*, vol. 9, no. 1, pp. 52–88, 2015, doi: 10.1111/sipr.12010.
14. J. D. West, J. Jacquet, M. M. King, S. J. Correll, and C. T. Bergstrom, "The role of gender in scholarly authorship," *PLOS One*, vol. 8, no. 7, Jul. 2013, Art. no. e66212, doi: 10.1371/journal.pone.0066212.
15. M. F. Fox, *Women, Men, and Engineering*. Chicago, IL, USA: Univ. Chicago Press, 2006, ch. 2, pp. 47–59.
16. M. C. Mattis, "Upstream and downstream in the engineering pipeline: What's blocking US women from pursuing engineering careers," in *Women and Minorities in Science, Technology, Engineering and Mathematics: Upping the Numbers*. Cheltenham, U.K.: Edward Elgar Publishing, Jul. 2007, ch. 14, pp. 334–362.
17. G. Ghiasi, V. Larivière, and C. R. Sugimoto, "On the compliance of women engineers with a gendered scientific system," *PLOS One*, vol. 10, no. 12, Dec. 2015, Art. no. e0145931, doi: 10.1371/journal.pone.0145931.
18. Y. Tao, "Where do they do engineering? Gender differences in employment at the position level among engineering doctorate recipients," *J. Women Minorities Sci. Eng.*, vol. 22, no. 1, pp. 69–89, 2016, doi: 10.1615/JWomenMinorScienEng.2016011999.
19. T. Camp, "The incredible shrinking pipeline," *ACM SIGCSE Bull.*, vol. 34, no. 2, pp. 129–134, 2002, doi: 10.1145/543812.543846.
20. J. Duch et al., "The possible role of resource requirements and academic career-choice risk on gender differences in publication rate and impact," *PLOS One*, vol. 7, no. 12, Dec. 2012, Art. no. e51332, doi: 10.1371/journal.pone.0051332.
21. C. Hill, C. Corbett, and A. St Rose, *Why so Few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC, USA: AAUW, 2010.
22. J. B. Main and C. Schimpf, "The underrepresentation of women in computing fields: A synthesis of literature using a life course perspective," *IEEE Trans. Educ.*, vol. 60, no. 4, pp. 296–304, Nov. 2017, doi: 10.1109/TE.2017.2704060.
23. M. Martonosi, "Statement on diversity at MICRO-50," Association for Computing Machinery Special Interest Group on Computer Architecture, Oct. 17, 2017. [Online]. Available: https://www.sigarch.org/statement-on-diversity-at-micro-50/

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