Examining the Prevalence of Gender-Exclusive Technology and Developing a Strategy to Combat Bias

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction - Women Have Long Been Underrepresented in STEM

The STEM industry (science, technology, engineering, and mathematics) is responsible for building the world. It drives technological advancements and scientific breakthroughs that have a heavy impact on society. However, one glaring issue within this industry is the underrepresentation of women. Women, who constitute roughly half of the global population, make up only 26.7% of the STEM workforce (Davies, 2022). The underrepresentation of women in STEM has broader implications beyond workforce diversity. It extends to the research, design, and development of technologies that affect our daily lives.

Technology is generally designed with men as the default and women as an afterthought. Since many technology products and services are designed with a one-size-fits-all approach (and most existing data is based on men), women are left with no choice but to use technology unsuited to their needs. Caroline Criado, feminist advocate and author of *Invisible Women: Data Bias in a World Designed for Men*, discusses the dangers of the absence of sex-disaggreaged data. She states “The gender data gap isn’t just about silence. These silences, these gaps have consequences" (Perez, 2019). Since women and men differ physically and psychologically, the use of these biased products can lead to increased risk of physical harm, inadvertently perpetuate gender biases, and create new social inequalities for women.

Addressing this gender disparity in STEM is not just a matter of equity and social justice; it's also essential for achieving a well-rounded and diverse perspective in problem-solving and innovation. In this paper, I delve into the origins of gender-biased technology, uncovering the root causes and exploring the implications of such technology.

Employing actor-network theory, I uncover the intricate workings of this system and present a deeper understanding of how gender bias exists and originates in technology.

Section 1 - Studying Gender Bias in Technology: Its Consequences and Causes

First introduced in 1975, “Reference Man” is defined as a male between 25-30 years old, weighing 154 pounds, and standing 5 feet 7 inches tall (Tapia, et al, 2021). Initially designed to help scientists understand the effects of radiation, Reference Man has since been used as a basis for the calculation of metabolism, pharmacokinetics, sizes for organ transplantation and ergonomic optimizations in the industry (Muller, 2022). Most medical education, practice, and research today still remains based on the Reference Man, a practice that completely ignores sex-based differences. The average woman is about three inches shorter and sixteen pounds heavier than the Reference Man. Women typically also have a higher percent of body fat, less bone mass, less muscle mass, narrower airways, smaller lungs, smaller and thinner bones, and smaller voice boxes. In addition to the visually different, there are differences in average blood pressures, resting heart rates, and other health markers between men and women (Muller, 2022). Moreover, disparities in psychological traits and societal expectations result in technology often failing to adequately cater to women's needs and experiences. These differences lead to unique approaches to technology utilization and distinct perspectives that are sometimes overlooked in design and development processes.

At the lowest level, these differences manifest as a daily inconvenience. For example, voice recognition technology (like Siri and Alexa), often struggle to understand female voices as accurately as male voices because the training data for these systems has historically been skewed towards male voices (Bajorek, 2019). Homes are built to

accommodate for the average man; mundane tasks like reaching the top shelf of a cabinet may never occur to men as a problem but is something many women struggle with. Even the standard temperature of an office was calculated on a male model. On average, offices are five degrees too cold for women (Perez, 2019).

However, more often gender bias in technology has serious consequences to the health and wellbeing of women. In places like the police force and the military, gear and clothing are typically designed for men. This causes issues because women have different body shapes and sizes. In the army, women have reported "removing protective side panels or putting pieces of foam under straps to reposition gear and ensure their organs were protected" (Prasad, 2019). Another issue lies in the safety testing of machinery. The auto industry, for example, has traditionally relied on male crash test dummies. It wasn't until 2012 that the United States started to include female dummies in car crash tests. This historical oversight has had serious consequences, with female drivers facing a 17% higher risk of fatality and a 73% greater chance of suffering severe injuries in car accidents (Barry, 2019). Even today, the female crash test dummies used are essentially scaled-down versions of their male counterparts, failing to accurately represent the unique anatomical differences between men and women. What's concerning is that many car manufacturers are known to design their vehicles with the sole aim of meeting minimum crash test standards and no further (Barry, 2019). If regulations do not demand comprehensive crash testing with female dummies, it means that cars may not adequately protect women on the road.

Lastly, women have long been excluded from medical trials and research. For decades, the popular belief was that the composition of men and women were identical

(apart from their reproductive organs) so there was no need to study women. Most of the cells, human *and* animal, studied in medical science have been male. Most advances in research have come from work done on a male subject, partly because "menstrual cycle, and varied release of hormones throughout the cycle" of women introduce too many variables into a study (Jackson, 2019). This line of reasoning is unfounded when we consider that menstrual cycles are not "outliers" but are instead a normal component of women's health that greatly impacts the effects of medicine and diseases. Due to biological differences, women are 50 to 75 percent more likely than men to experience an adverse drug reaction. In 2000, the U.S. GAO (Government Accountability Office) reviewed drugs approved by the FDA and ended up pulling ten drugs from the market, eight of which were pulled due to having caused severe side effects in women (Whitney et al., 2019). According to Dr Janine Austin Clayton, an associate director for women's health research at the United States National Institutes of Health, "We literally know less about every aspect of female biology compared to male biology" (Jackson, 2019). Even disease symptoms present differently, resulting in under-diagnosis and mistreatment. Additionally, due to the lack of research on women's health, there is less information and treatment overall for women-specific diseases.

Biological differences are not the only reason behind women being more at risk of physical harm. Take for example the snowy town of Karlskoga in Sweden. The town's snow clearing schedule, a seemingly innocent routine, actually helped the safety of men at the expense of women. Snow was cleared first on main roads leading into the city, benefiting commuters—who were mostly men. Foot- and cycle-paths were cleared

last—not so good for pedestrians and cyclists, who were very often women. As a result, 79% of pedestrian injuries occurred in winter, of which 69% were women.

Furthermore, the prevalence of biased technology and its disregard for gender differences not only jeopardizes women's safety but continues to uphold and promote harmful gender stereotypes. Historically, video games have frequently depicted women in stereotypical or objectified roles that primarily cater to male players. Based on a study done at EDHEC Business School, it was found that 87.1% of characters in Assassin's Creed are male and that they perform 90.2% of speaking lines (Guintcheva, 2019). Even household objects hold an agenda. When the Philips electric shaver entered the market in the late 1930s, the company had little differentiation between shavers of each gender. However, further iterations started to show off the technology of shavers for men but masked the technology for women. Men's shavers had "black and metallic colors and bolder shapes"' with "information and control possibilities" while women's shavers had "perfume to mask the smell of oil...and eliminated visible screws" and were marketed to be associated with cosmetics (Trevor et al., 2005). Figures 1 and 2 provide a visual of the shavers described.

Figure 1. The Philishave (Trevor et al., 2005)

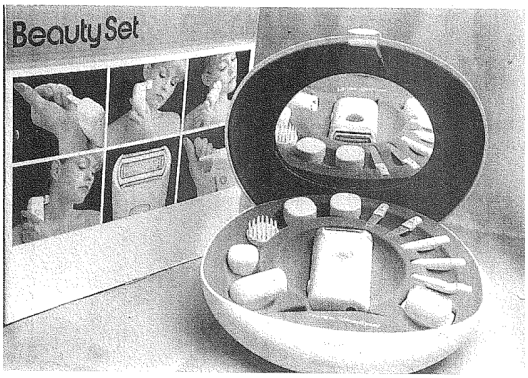

Figure 2. The Ladyshave (Trevor et al., 2005)

Lastly, design resulting from a gender-biased environment has the potential to introduce new social inequalities. Emerging AI technology has the ability to separate men and women into two different playing fields. AI algorithms are used to push job advertisements, scan resumes, provide medical predictions, and more. Again, a historical lack of diverse training data has caused AI to work against women. On online job platforms, researchers found that "setting the user's gender to "female" resulted in fewer instances of ads related to high-paying jobs than for users selecting male as their gender" (Huet, 2022). A study by the World Economic Forum found that certain widely used AI screening tools discounted resumes containing words like "women's" by 8% compared to male-associated words like "men's" (Aouf, 2023).

Why do engineered products hold such bias? Whether intentional or not, products usually reflect the people who designed them. I-methodology is a design practice in which "designers consider themselves as representative of the users" (Perez, 2019). Because the STEM industry is male-dominated, the products and services that result are more often than not geared toward men. Beyond simply increasing the number of women working in the STEM industry, a process which would take decades to see the full effects of, more immediate solutions need to be implemented. It is unclear where change needs to occur, so I aim to dive deeper into this problem to answer the question of how to identify and mitigate gender bias in technology.

Section 2 - The Application of Actor-Network Theory (ANT) in Analyzing the Relationship Between Gender and Technology

Actor-Network Theory (ANT) has become a vital framework for comprehending the intricate relationship between technology and society. Rooted in the idea that

technologies are not isolated from societal influences, this essay explores the application of ANT in the context of gender and technology. (ScienceDirect Topics, n.d.).

In an article titled "Actor-Network Theory and its role in understanding the implementation of information technology developments in healthcare," the author Kathrin Cresswell argues for the importance of using ANT perspectives in health services research and evaluations of IT systems in health service organizations (Cresswell et al., 2010). In the article, Cresswell states that countries have been increasing their use of IT in healthcare settings under the belief that improvements in information flow will translate into improved quality of care. However, in actuality it is not so simple since " inputs are often transformed into unpredictable outputs," especially where "many different groups use various technologies in complex ways" (Cresswell et al., 2010). Because of the complex nature of reality, studying IT in healthcare requires the simplification of reality, but not so much that nuances are lost. This is where ANT comes in, which looks at how different stories are related in order to gain insight into the full picture that one is studying.

The central idea of ANT is to investigate how networks came into being, trace what associations exist, and look at how the network and actors move. Mediators, which are variables that transform inputs into unpredictable outputs, can form relationships between actors and play a big role in ANT analysis. Additionally, instead of viewing objects as passive sources of information, they now play an "active role that is determined by their position in the ever-changing network" (Cresswell et al., 2010). This challenges the separation of the material and human world and provides a good tool for investigating complex relationships between human and non-human actors.

To showcase the active role of objects, Cresswell provides an ANT analysis of electronic health record software. Prior to the software's introduction, nurses informally ordered x-rays on paper forms that were pre-signed by clinicians. After the software was introduced, nurses lost the ability to order x-rays due to restricted access, forcing clinicians to do it themselves. The actors in this scenario include the new software, nurses, healthcare professionals, other healthcare staff, patients, paper, and medical equipment. Figure 3 below shows a simplified illustration of the network of actors. All actors, human and non-human, were reorganized to exist around this new actor. ANT can help to gain a deeper insight into the effects and be used to give recommendations of how to make the new network more stable and in doing so facilitate the effective integration of the technology into the environment.

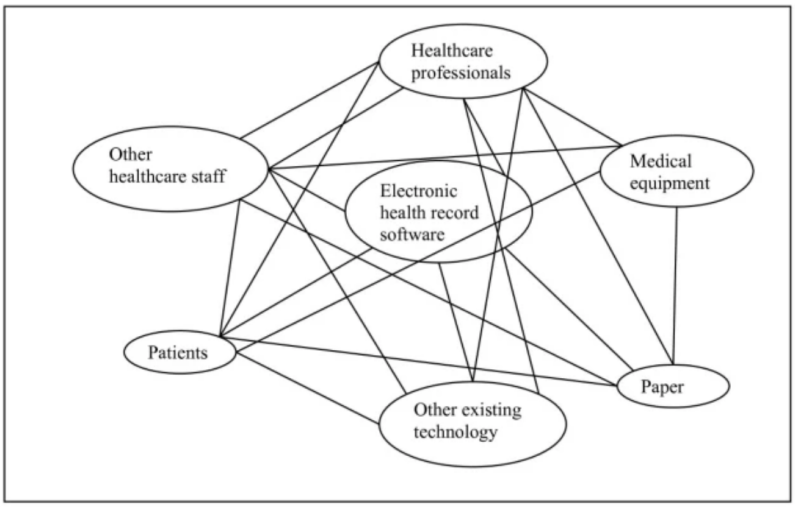

Figure 3. Actor network of the introduction of an electronic health record system (Cresswell et al., 2010)

Although Cresswell's argument is for the application of ANT Theory in understanding IT development in healthcare, the argument can be applied to the broader

context of technology development in all industries and aspects of life. Just like how IT development should translate into improved patient care, innovation in the sociotechnical system should translate into improved quality of life. I identify actors of the system to create a network that can be used to provide insight into what leads technology to be received with gender bias.

The first actor to look at is technology itself, which includes both the tangible and intangible. Software, algorithms, web applications, machinery, tools, engineered objects, scientific advancements, and medicine all fall under this umbrella. Artifacts that are more commonly used or that have a greater impact may have stronger connections with the rest of the actor network.

In the context of this paper, users of technology are categorized into two distinct groups: men and women, both bearing equal significance and representation.

Technology creators encompass a diverse array of human actors including researchers, engineers, scientists, medical professionals, mathematicians, educators, regulatory bodies, and others connected to the STEM field. The actors within this category hold varying degrees of influence and power, thereby influencing their respective importance in the overall network dynamics. For instance, while researchers play an essential role, their capacity for immediate and sweeping impact differs from that of governing bodies capable of enacting new regulations.

Research data, societal expectations, industry regulation, and engineering practices constitute the final set of influential actors in this complex network. Their influence is channeled through the human actors within the network, subsequently shaping the sociotechnical system.

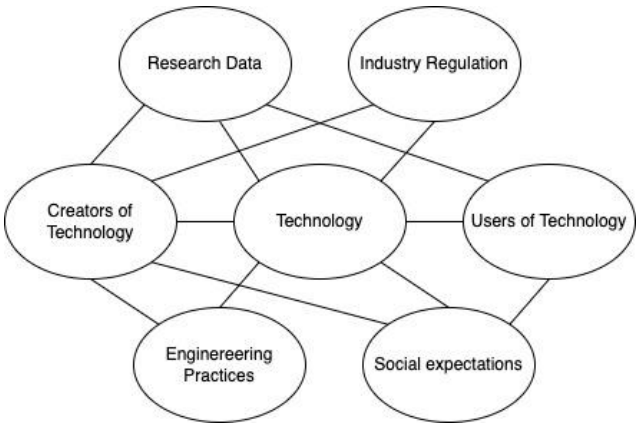

Figure 4. Key actors in the relationship between gender and technology. (Created by author)

Looking at Figure 4, we can see how technology engages in direct interactions with both human actors and their non-human counterparts, creating a dynamic web of relationships. Research data, societal expectations, industry regulation, and engineering practices act as mediators that influence the final results of technology. These components are what make the network potentially unstable, and are what need to be addressed to successfully eliminate gender bias in technology.

Section 3 - A Strategy to Identify and Combat Gender Bias

This section explores the mediators that were identified and their significance in influencing the other actors of the network, directly impacting whether gender bias is present in technology. In addition to influencing the other actors, they also influence each other. Knowing how each mediator works within the network, it can be predicted if an input (technology) results in an unexpected output (gender bias).

Firstly, research data can greatly impact the functionality of technology. Take AI art generators, which when asked to generate an image of a CEO, typically show a man. The training data may reflect societal stereotypes and biases that associate certain

professions or roles, such as CEO, with specific genders. Although engineers may not have intentionally designed generators with gender bias, biased training data unintentionally affected the generator's output. Societal expectations further shape both the creation and reception of technology. Historically, men have been encouraged to pursue STEM careers more than women, and that is reflected in the demographic of the industry. Consequently, when decisions are made, falling to I-methodology usually results in male-catered design. Women also stand in different places in society than men, and thus expect different needs from technology. Lastly, industry regulation and engineering practices play a role in the design process of technology. They may inadvertently perpetuate bias and create obstacles that push women out of the system, resulting in biased technology. For example, women in drug trials are required to be on birth control due to the adverse side effects it could have on fetuses. While this is necessary to ensure the wellbeing of the women, this increases research costs and is a reason industries are reluctant to include women in testing.

Understanding the influential role of mediators in shaping networks allows for a more proactive identification of potential gender bias in technology. Rather than discovering gender bias in a piece of technology after its release, bias can be spotted and eliminated before any consequences occur. It can also be used to fix existing gender bias in technology. To validate the effectiveness of this approach, it can be applied to the snow cleaning schedule in Karlskoga, and the identified issues can be compared with the implemented solution. Historically, the town's cleaning schedule prioritized clearing highways, main roads, local roads, and, lastly, walkways and bike paths. Considering societal expectations, it becomes evident that women are often more engaged in domestic

responsibilities, such as taking care of children, grocery shopping, and elderly relatives. As a result, women tend to take indirect routes and rely more on public transportation and walkways. So when local roads and bus routes in Karlskoga became impassable due to snow, women resorted to walking. Common practice is to clear main roads first, so the schedule was likely also implemented without stopping to consider if it made the most sense. Additionally, given the historical predominance of male leadership, it is likely the planning department consisted of mostly men, who lacked the perspective to see any issues. Taking these factors into account, it makes sense to prioritize clearing walkways first. The real-world solution aligns with these findings, since in 2013 the schedule was swapped to clear footpaths first and main roads second and accidents decreased by half (Lebus et al., 2020).

ANT can also be used to analyze the use of aspirin for heart disease prevention. Aspirin has traditionally been recommended for the prevention of heart attacks and strokes, as established by the trial known as the Physicians' Health Study in 1982 (Jackson, 2019). The research involved 22,071 male participants and no women, yet no distinction was made in the assertion that aspirin could enhance heart health. Additionally, societal values have long led doctors to systematically ignore the differences in biology between men and women, and even disregard women altogether as a test subject. Because women were traditionally valued primarily for their child-bearing abilities, before the 90's, institutes reasoned that "since women are born with all the eggs they will ever produce, they should be excluded from drug trials in case the drug proves toxic and impedes their ability to reproduce in the future" (Jackson, 2019). The result was that all women were excluded from trials, regardless of their age, gender status, sexual orientation or wish or

ability to bear children. As mentioned earlier, women as test subjects are also more expensive due to them requiring birth control. Lastly, the practice of viewing the menstrual cycle as inconvenient and an outlier could have been another reason for researchers to exclude women from trials. This case study shows how imbalance in the actor network came from all four mediators and identifies them as areas that need change. From this analysis, it could be recommended that a new study be conducted with an equal number of men and women, that the researchers be taught not to let implicit biases and outdated practices dictate the fairness of their work, and that a funding initiative be created to support the cost of women in medical trials.

Conclusion

This paper brings awareness to the systemic nature of gender bias in technology, demonstrating how it is present in even the most mundane of innovations. If left unchecked, the social consequences that result from gender-biased technology only reinforce the factors that caused it, creating a vicious cycle. I look into various technologies and breakdown how the way they were created and/or received led to the presence of gender bias. Lastly, I apply ANT analysis to the sociotechnical system and use my research to effectively identify actors and build a network. The result of the ANT analysis is that the previously unpredictable outcome of a technology being gender-biased can now be predicted and the framework used to recommend solutions.

The strategy that I identified to combat gender bias is generalized to address a broad definition of technology, when in reality each piece of technology has its own unique set of actors. To increase its effectiveness, actors can be added/removed to suit the circumstances of every situation.I also only analyzed bias in technology through a

gender-focused lens. My analysis does not account for other forms of biases such as racial bias. This was done to limit the scope of my research, as a wider focus would complicate the actor network with too many unrelated elements. However, similar networks can be constructed with a different bias in mind for each in and utilized in order to create truly inclusive technology.

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