Inherent Gender Bias in Women Safety and LLMs with Special Emphasis on Engineering Design Defects and Technological Aspects

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ABSTRACT

Current safety and technology systems often overlook the unique needs of women. Issues with crash test dummies, stab vests, CPR techniques, and AI systems reveal significant risks and discomfort for women due to designs based primarily on male standards. Addressing these issues requires integrating female-specific models in safety tests, improving the design of protective gear, and correcting biases in AI systems. Implementing these changes will ensure that both men and women receive fair and effective protection, making technology and safety measures more equitable and reliable for everyone.

Keywords: *Gender Bias, Flawed Technology, Women Safety, Stereotypes, Biased data, Inclusive Design.*

I: INTRODUCTION

Women face a unique challenge with respect to essential safety protocols in potential life or death situations. Not only are men considered the standard benchmark for any safety tests/methods, but women are often not taken into account with respect to the gender differences based on anatomy and structures. Such disparity often has fatal consequences for women. For instance, according to a 2021 Study by IIHS: Women are 2.5x more likely to suffer a moderate leg related injury and 70% more likely than men to suffer serious leg injuries(IIHS-HLDI 2021)even though nearly half of the legally licensed drivers are females. This paper will explore the technical issues related to gender bias in safety protocol and the inherent sexism in machine learning algorithms-primarily focusing on how CPR techniques, Crash test dummies and stab vests fail to account for the anatomical and biomechanical differences between men and women & the gender bias and stereotypes showcased by Voice assistants and Chatbots-and its historical significance and will provide some viable alternatives.

For decades safety standards have relied on tests and research primarily focused on the male body and its physique. This has led to creation of protective equipment and safety measures that are not optimised to safeguard women. Furthermore, technology that should display gender neutral behaviour often shows bias to certain stereotypes(Such as Voice Assistants and LLMs).Recently, Virtual Reality Environments such as Metaverse have become an active ground for reports of sexual harrasment and violation of privacy, yet there are no legal provisions to provide punishments to such offenders nor do the developers actively try and resolve the issue through software design.

One of this paper's aims is to bring forward such cases which are often not addressed all around the world, especially in developing countries. It acts as a part of a collective programme to neutralise any sort of gender bias in terms of capabilities.

Traditional crash test dummies are modeled after the 50th percentile male(represents a mid-sized adult male and has a seated height of 88.4 cm and weight of 77.7 kg)[*INTERIM REPORT to CONGRESS*. 2022], neglecting differences in female body sizes, muscle mass, centre of gravity and anatomy. Almost all countries have no legal mandate for the use of female dummies. Female 5th percentile dummies are also used, although, rarely. However, these dummies are usually smaller versions of the male dummies, not

accounting for differentiating features such as weaker necks, spinal alignment, pregnancy and also a wider pelvis.As a direct consequence, women(including pregnant women) sustain more severe injuries than men in comparable crashes(Stanford Gendered Innovations; Schiebinger 2011).Moreover, the female gender was associated with more head, thorax and extremity injuries.(Carter, Patrick M., et al.,2014)

According to the American Red Cross, among cardiac arrests that happen in public, men have a significantly higher probability to receive CPR assistance compared to women. Furthermore, current CPR methods, primarily focused on dummies based on males, require a higher mean compression force than women, who have a softer chest compared to males(Tomlinson, A.E. , et al.,2007).

Another topic for concern are police worn ballistic vests which are designed to protect crucial organs in the torsa from gunshots and projectiles. However, the ballistic vests for police officers are usually engineered using laminated fabric which is nonflexible and heavy, creating a poor fit for the female body; thus, it is unable to provide adequate protection(Mica, M. T. & Peksoz, S. -.,2020).

Artificial Intelligence is transforming our lives, data driven machine learning models such as search engines, navigation applications, voice assistance and chat-bots trained on LLMs have exponentially increased development in almost every sector. However, it is not without its flaws, research shows that algorithms are trained on large sets of data which is biased due to societal stereotypes and norms, resulting in discrimination towards disadvantaged group (Buolamwini, Joy, and Timnit Gebru).These machines are trained using information generated using online activities along with analytical tools, thus, much of the information is often biased and contains radical thoughts against women. Due to this, various types of data sets based often lack attention due to the lack of awareness about them among societies. One such example of this is the misdiagnosing of certain ethnicities and genders in hospitals with ever increasing AI dependence , causing these inequalities to become more evident(Schumacher, Clara, et al.).Voice Assistants and Chat-bots which are often trained using such models have also become part of the problem. Voice recognition softwares often have difficulty in recognizing female voices, this can cause a threat to their life. Such systems are often used in cars and other vehicles, if the software malfunctions during a car ride when a female driver is controlling the car, it can cause them to get irritated and distracted, potentially causing life threatening injuries. This flaw, along with female underrepresentation in crash test dummies can make driving a life threatening experience for women.

This paper will use existing practice research and surveys in these topics to create another perspective on this issue, further developing awareness in this topic.

By analyzing the current shortcomings of such protocols and models, this paper aims to raise awareness about gender bias in protection and inherent sexism in LLMs(Large Learning Models) and Virtual Reality environments. It will also explore the engineering defects which cause a disadvantage to women, and some new technology that can be used to correct these defects. The paper will also provide a brief introduction to the engineering principles behind crash test dummies and stab vests. Finally, the paper will discuss advancements and propose some recommendations to enhance the field of safety engineering.

II Crash Test Dummies

An anthropomorphic test device (a.k.a Crash Test Dummy) is an accurate test device used to measure the extent of human injuries during vehicular crashes. They include various sensors which provide information about human responses to impacts, accelerations, deflections, and forces of inertia during a crash.
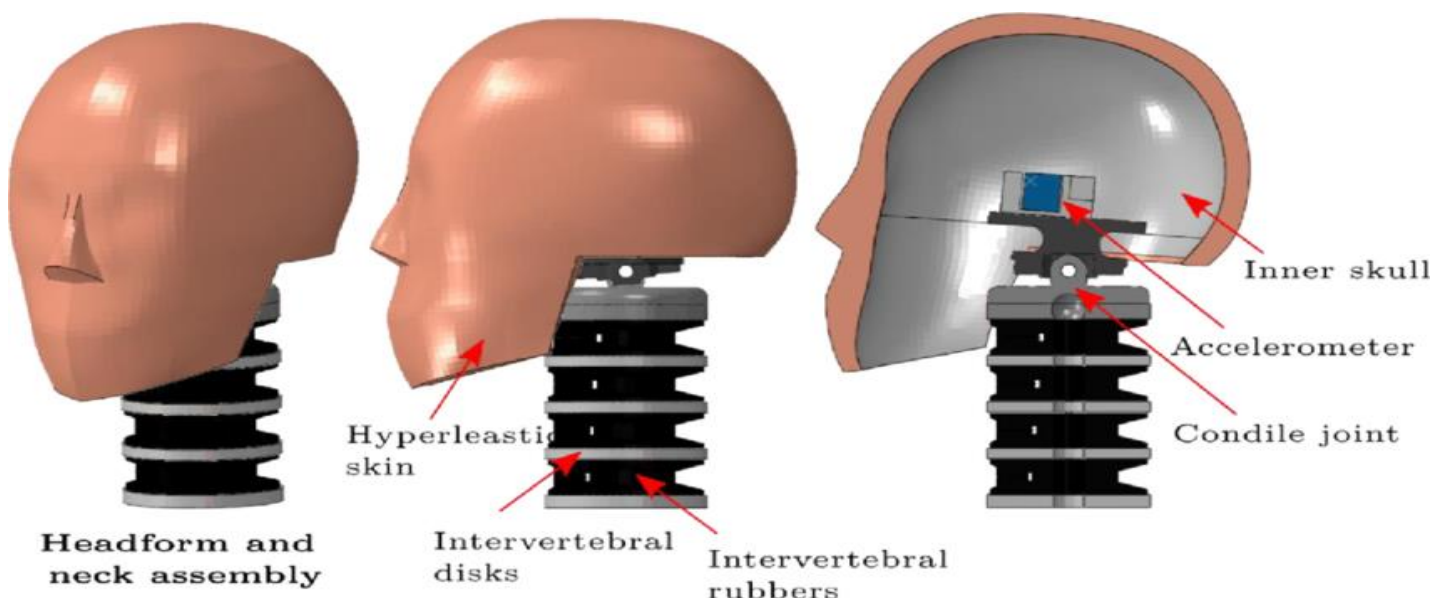
History:

After World War 2, crash tests were conducted on corpses or volunteers. However, finding corpses without any external injuries or internal damage was difficult. As awareness about the importance of life spread around the world-there was also a lack of volunteers, causing engineers to create Dummies that could replicate a man(Naukowe, Zeszyty, et al).

In 1949, Alderson Research Labs and Sierra Engineering created the first crash test dummy, Sierra Sam, to test aircraft ejections, aviation helmets and pilot belts [Humanetics;History].

Engineering principles used:

The 50th percentile man dummy- representing an average male of 172cm height and a weight of 78.4 kg-from the Hybrid III set is the most commonly used dummy in crash test, it is also a part of the BNCAP(Bharat's New Car Safety Assessment Program) project, India's latest crash safety program, also used this dummy for Frontal Impact tests.

Headform and neck assembly | Hyperleastic skin | Intervertebral disks | Intervertebral rubbers | Inner skull | Accelerometer | Condile joint
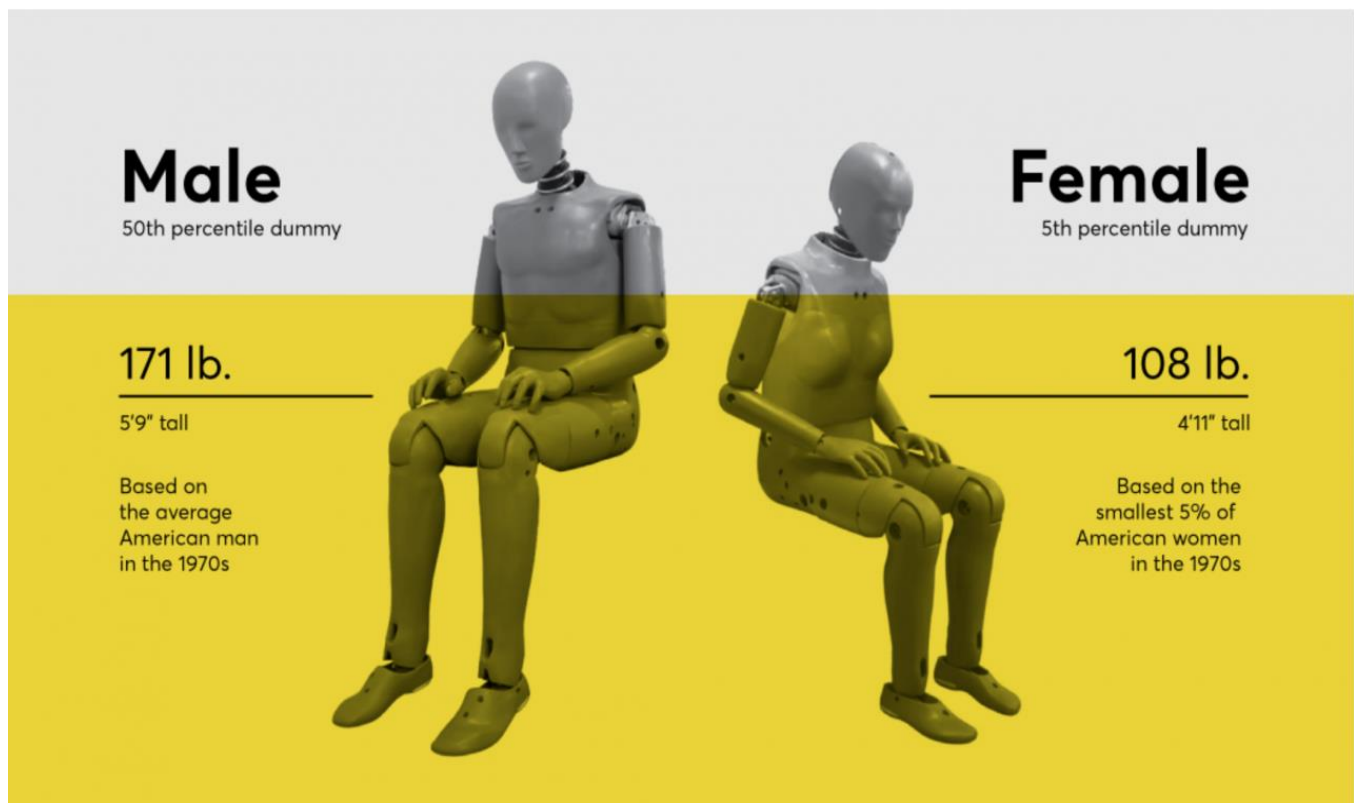
 (Millán et al.,2023)Image
The Dummy Head is made up of aluminium and is coated with flexible rubber. The Interior includes three sensors which measure:
1)The force of Impact
2)Angular Head Displacement
3)Acceleration during a collision with an obstacle.
The neck-includes a potentiometer, whose task is to measure the deflection of the spine against the spine. The sensors also help understand the stress on the spine during forward and backward movement while a crash is occuring (Naukowe, Zeszyty, et al).

(ElProCus,.2017)Image

The Hybrid III 5th percentile female dummy maps the woman to a short height - 150cm and weight of 50kg.It represents the smallest piece of adult women population. It helps understand the behaviour of the chest during a accident as accelerometers are mounted on the breastbone and other measuring equipment is used to measure the deflection between the spine and breastbone.(Naukowe, Zeszyty, et al).

Male
50th percentile dummy

171 lb.

5'9" tall

Based on
the average
American man
in the 1970s

Female
5th percentile dummy

108 lb.

4'11" tall

Based on the
smallest 5% of
American women
in the 1970s

("Women at Risk due to Lack of Female Crash Test Dummies | Team-BHP.")Image

The table below shows the full-scale anthropomorphic test device requirements for India's latest Car Crash Safety programme, BNCAP, which states that there are no requirements for a female test device, not even a 5th percentile model.

Sr. No.	Test	Test Dummies		Test Speed	Area of Assessment	Test Protocol
		Adult	**Child**			
1	Offset Deformable Barrier Frontal Impact Test	02-Hybrid-III 50th percentile dummies at front outboard seating positions	Q-Series Child Dummies 01-1.5 year old and 01-3 year old Child dummies at 2nd row outboard seating positions	64 km/h	Adult and Child Occupant Protection	Annexure I
2	Side Impact Test	01-EuroSID2 dummy at Front driver seating position	Q-Series Child Dummies 01-1.5 year old and 01-3 year old Child dummies at 2nd row outboard seating positions	50 km/h		Annexure II
3	Pole Side Impact Test	01-EuroSID2 dummy at Front driver seating position	Not Applicable	29 km/h	Adult Occupant Protection	Annexure III

Table No. 1 – Tests for BNCAP

[BNCAP.,2023]

Compared to men, women have a higher risk of injury to all major regions of the body which can cause fatal implications.A study by the University of Virginia estimates that a woman is 73% more likely to be injured in a frontal impact vehicular accident compared to males(Vanella, Julia.,2023).Yet, in many car safety programs, women continue to be ignored in frontal impact crash tests-they either place the women dummy in the passenger seats or exclude them from tests.

The 5th percentile female dummies are just smaller version of the average male dummies and do not account for:

1)Female Structure like the shape of the torso
2)Female muscle mass and ligament strength
3)Spinal Alignment
4)Mass distribution across the body.(Stanford Gendered Innovations;Schiebinger 2011)

Though these problems have yet to be given proper attention and the required funding, there are various potential solutions to these problems which can promote gender equality and a more inclusive society where differences put any gender at a disadvantage.

1) Introduction of laws to integrate female dummies in Vehicular safety assessments:
The introduction of various advanced female crash test dummies, such as the THOR-5F, represent significant technological breakthroughs in addressing issues such as gender bias in safety engineering. These dummies are designed accurately to represent the female body[16]..Integration of such dummies in programs such as BNCAP shall be made mandatory to see any sort of progress in this issue.
2) Gender specific sensor integration:
Recently made, modern crash test dummies are often equipped with sophisticated sensor systems, allowing for detailed data collection on injury patterns in vulnerable areas such as the thorax and spine for women.
3) Computer Simulations for representation:
Often times, the creation and usage of new dummies can not only be a time taking process but also extremely expensive due to which companies may shy away from the usage of new dummies. Thus, to complement physical tests, researchers should utilize advanced computer simulations, these allow for an even broader range of specifications to physiological factors, enabling a comprehensive analysis of crash impacts.

III. Stab Vests & CPR Methods

Gender-Bias in the design of stab-vests has been a widely discussed issue; these discussions mainly focus on the unsafe structure and uncomfortable experiences for female officers. Ballistic vests(stab vests) are constructed with multiple layers of high-performance material, which makes the vests uncomfortable and heavy. This issue, along with the poor fit of the vests for female officers due to the vests not taking into account the difference in the female body shape, affects efficiency and compromises the protection of female officers(Mica, M. T. et al,2020).Such ignorance in taking up these issues and fixing them result in female officers opting to remove their stab vests due to discomfort. These choices, in some cases, can result into fatal consequences during critical moments which was the case with British police officer Nina Mackay, who was fatally stabbed after removing her stab vest in 1997(De Camargo, Camilla.,2023).

Gender disparities are, surprisingly, also present in CPR training and practices. Research suggests that only 39% of women experiencing cardiac arrests receive CPR, compared to 45% men(Michael, "Do Women Receive CPR Less than Men | Operative Experience").Such disparity often results in the fact that women experiencing cardiac arrests are more likely to have fatal consequences compared to men. These differences become further pronounced due to the dominance of male-oriented training material and dummies lacking female anatomical differences. Most CPR dolls only represent male torsos; furthermore, dolls with breasts are almost never present in training facilities, especially in developing countries.

A questionnaire was conducted and answered by 9 female police officers and detectives who are required to wear stab vests and ballistic vests in the line of duty. The results were also follows:

Theme: Fit problem
1) Not cut out to shape: Mentioned by 78% of participants
2) Needs to be tailored: Mentioned by 33% of participants

Theme: Effect of poor fit:
1)Chafing: Mentioned by 44% of participants
2)Choking: Mentioned by 11% of participants

Theme: Areas of Discomfort:
1)Chest Curve: Mentioned by 89% of participants
2)Waist Curve/stomach: Mentioned by 45% of participants

Theme: Uncomfortable movements:
1)Running: Mentioned by 78% of participants
2)Bending over: Mentioned by 78% of participants

Theme: Factors affecting movements:
1)Weight and flexibility of vests: Mentioned by 11% of participants
2)Too tight in the back: Mentioned by 11% of participants

(DATA TAKEN FROM (Mica, M. T. et al,2020))

These were just some of the issues discussed and mentioned by the officers in the survey, showcasing the urgent need to improve the design of these vests-not only for the comfort of the officers but also to ensure that crime rates do not increase due to decreased efficiency.

Recent advancement in fabric technology and greater understanding about how different polymers and materials work with stab vest designs have led to various innovations. Such as developing new polymers inspired by nature, which are used in areas such as Energy absorption & Armor design.3D Printing is a process which provides great freedom in terms of creation of stab resistant structures. Integration of lightweight, high strength materials such as UHMWPE(Ultra High Molecular Weight Polyethylene), which has dynamic stab resistance due to the presence of STF that descreases yarn mobility and accelerates the counter-response process and aramid fibres which can increase the comfort for officers(Li et al.)(Panneke and Ehrmann).Design features now include considerations of female anatomy, such as waist darts which help accommodate the waist curve, increased elasticity of inner fabric layers to provide a wider range of motion and some other modifications such as difference in stitching which can potentially convince female police officers to wear vests while also providing extra protection(Mica, M. T. et al,2020).
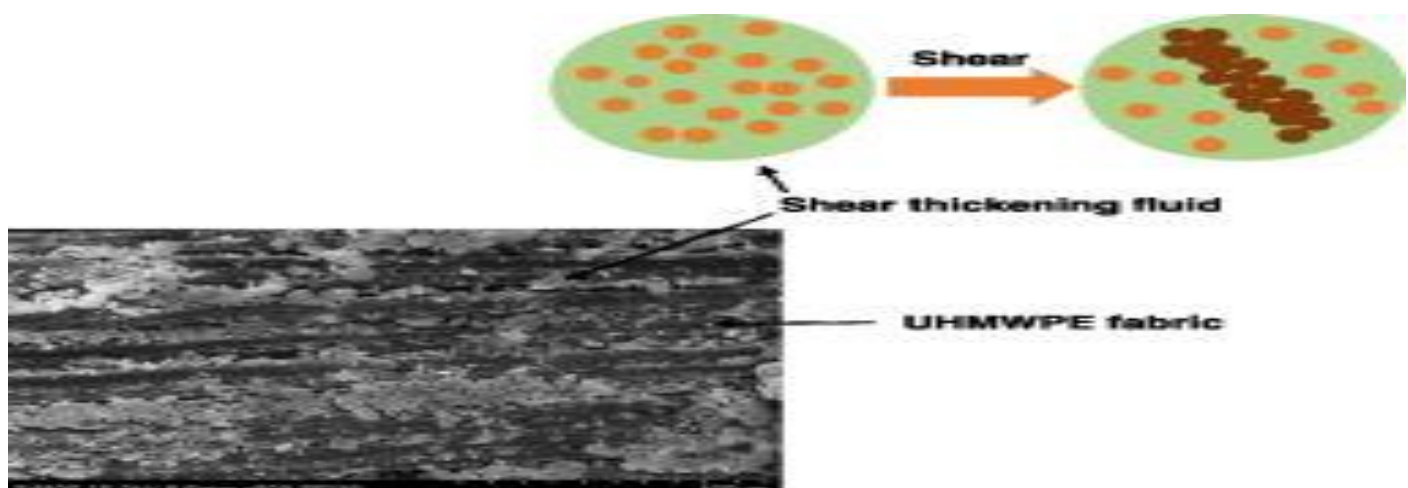
(Li et al.)

Research can be done in this field with a large-scale participation of women officers to create prototypes with expected design features which can slowly be integrated into police programs.

New initiatives in CPR training have also focused on gender-sensitive training. These initiatives focus on the introduction of anatomically accurate female training manikins, which feature breasts and aim to reduce bias among trainees while performing CPR on women(Treisman).Such efforts have proven to be extremely effective for providing assistance during times of emergency, improving response rates and survival outcomes. Another way to increase efforts for such issues is by understanding symptoms of cardiac arrests in women-such as gastrointestinal issues, Seizure-like activity and flu-like symptoms(Rauf)- which differ from the male benchmark symptoms(Michael, "Do Women Receive CPR Less than Men | Operative Experience").Furthermore, simulation training- such as the one provided by the Operative Experience Inc- should be provided in training facilities to get familiar with lifelike skin, realistic body weight, symptoms and also different skin tones to provide effective CPR conducted by both first responders as well as bystanders during life of death situations(Michael, "Do Women Receive CPR Less than Men | Operative Experience").

Recognizing and addressing such historical biases in design and application of stab vests and CPR training are essential to improve outcomes of potentially fatal instances. Through innovative engineering ideas and inclusie training programs, stakeholders can create a safer environment for all individuals. The ongoing commitment to enhance gender inlusivity in stab vests and CPR training showcases the improvement of mindset in our system. For this to further improve, integration feedback mechanisms to constantly improve designs is also essential in addressing safety concerns.

IV. Voice Assistants & Chat Bots

Inherent gender bias in chatbots and voice assistants which are trained by large language learning models(LLMs) is a significant issue in the field of machine learning and the flawed system of data collection which often goes under the radar.This bias mainly stems from the data which is used to train these models, which often do not have any filters to remove biased data.

LLMs are trained on data sets which are sourced from the internet, these often contain information which can reflect gender stereotypes. Due to the absence of any barrier, this is learned by a system and eventually spreads to all other systems.For example, a study demonstrated that word embeddings, an essential component of NLP(Natural Language Processing), can showcase gender bias and sexist comments during training(Bolukbasi, Tolga, et al.).

Algorithms used in these systems can also unintentionally convey bias through optimization techniques and model architectural selection. Much of the information on gender can be overrepresented or underrepresented in ways that can skew any machine's behaviour and responses.

The way users interact with chatbots and voice assistants can also cause gender bias. Users often feed in biased information into an AI's database, which influences the AI's adaptation process. Automatic captioning systems on platforms like Youtube also exhibit gender bias, often performing with less accuracy for women(Tatman, R. 2017.).

NLP models can also show gender bias, this can lead to skewed and biased language understanding, causing abnormal language generation. Data, such as those collected from social media interaction, show that these models spread stereotypes by associating certain professions and characteristics more frequently for one gender compared to another.An analysis by Bender et al(2021)found that common models generate stereotypical association, like linking "doctor" with "he" and "nurse" with "she"(Bender, Emily, et al,2021).

Another area where the discussion of gender bias goes under the radar is in voice assistants like Siri,Alexa and Google Home. These assistants have different accuracy rates for male and female voices. Studies also show that these systems perform better with male voices due to biased data sets.Research also indicates that google's speech recognition system had a 13% higher word error rate for female voices compared to the male counterpart(Tatman,R.2017.).

With the turn of the decade, various companies have also started using AI-powered recruitment tools that utilize the same complex datasets as other LLMs which contain data about resumes and professional profiles. These systems, working on skewed results from the data sets, might favour male candidates by learning from past hiring patterns, job requirements and historical skill assumption to reflect patriarchy. A study revealed that there is need for evaluation of these tools and a filter to avoid showcasing historical biases and stereotypes in hiring. For instance, Amazon's AI recruitment tool flagged resumes for review that included the word "women's".Furthermore, in fields such as software engineering, male candidates were 1.5 times more likely to be recommended for interviews compared to women[Raghavan, Manish, et al.2020].

Thankfully, rapid technological development in the AI & ML field makes these issues relatively easier to handle compared to other instances of gender bias.Solutions to address gender bias in these areas can often be implemented quickly given that these issues are given appropriate attention.

1. Implementation of algorithmic fairness techniques- which involve using bias detection filters, adversarial debiasing, and fair representation learning-are essential to ensure unskewed filtration of datasets.AI Fairness 360 is a toolkit developed by IBM to help increase fair algorithms in industrial settings and create an environment for fairness researchers to share their ideas[Mehrabi, Ninareh, et al,2021].Various researchers also discuss fair representation learning-which aims to reduce gender bias in machine learning models by measuring the extent of bias in the model's outputs and training the model to learn representations of data that are ignorant to gender.[Madras, David, et al.2018]

2. Diverse and balanced datasets are necessary to ensure that there is not an underrepresentation or overrepresentation of any group or community in the output of machine learning models. The SMOTE technique(Synthetic Minority Over-Sampling Technique)- which is a data augmentation technique to address class imbalance by generating synthetic samples for underrepresented classes- can significantly improve the imbalance problem in gender classification form the data-level perspective.[Ahmad Haadzal Kamarulzalis, et al,2018].

3. Development of gender-neutral/gender ambiguous voice models will also play a pivotal role for the overturning of this issue. The creation of "Q", a gender neutral voice assistant showcases an example that such initiatives can make a difference. Providing voice customization options also helps reduce the normalization of gender stereotypes.

V. Conclusion

The research shows a notable difference in safety and technology features, with a consistent preference for male users. This disparity between genders is clear in areas that include automotive engineering and medical technology. The lack of female biological factors in design and testing has resulted in inadequate protection for women from injury or harm due to underrepresentation.

A fundamental change in thinking is required to reduce these risks. It is crucial to include anthropometric data specific to females in design and simulation models. Furthermore, it is essential to create thorough testing procedures in order to confirm the effectiveness of safety measures for women. Utilizing sophisticated technologies like machine learning and artificial intelligence can help identify and address gender inequalities in data. Skewed data results can be fixed by filtering out radical thoughts and data which does not align with modern ideologies and spread stereotypes throughout a system.

By placing emphasis on gender inclusivity in engineering and technological advancement, we can establish safer and fairer spaces for everyone. Achieving safety systems tailored for both male and female users is necessary in the future. It will be essential to create standardized methods for designing and testing that are inclusive of all genders. Additionally, allocating funds for studies on the relationship among gender, biology, and conflict management will yield valuable knowledge for upcoming advancements. By collaborating, we can establish a future that is both safer and more fair for everyone.

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