Beyond "Pink" and "Blue": Gendered Attitudes towards Robots in Society

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ABSTRACT
Developing an improved understanding and awareness of how gender impacts perceptions of robots and interactions with them is crucial for the ongoing advancement of the human-robot interaction (HRI) field, as a lack of awareness of gender issues increases the risk of robot rejection and poor performance. This paper provides a theoretical grounding for gender-studies in HRI that illustrates potential dangers of "pink" versus "blue" dichotomous over-simplifications of women and men, and advocates for including potential users of both sexes. We further present the results from an exploratory survey of women and men's attitudes toward robot development that demonstrates how real-world gender differences on attitudes toward robots go beyond simplistic generalizations. We envision that this work will provide HRI designers with a foundation and exemplary account of how gender can influence attitudes toward and interaction with robots, serving as a resource and a sensitizing discussion for gender studies in HRI.

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Gender studies; human-robot interaction; robot design

ACM Classification Keywords
H.5.2 [User Interfaces]: Theory and methods

INTRODUCTION
Robots are poised to enter a range of personal spaces and contexts such as homes, classrooms, or hospitals, and the sociological investigation of how robots will integrate into people's environments has been an important component of human-robot interaction (HRI) research (e.g., [53]). It is still unclear, however, how a person's gender will impact perceptions of and interactions with robots.

The fields of sociology and gender studies highlight how technology, science and gender are tightly intertwined [7, 8, 49]: gender impacts how scientific knowledge [40] and technologies [14] are developed, appropriated and used [47], and understood by society [2]. For instance, although the microwave oven was originally targeted primarily at men for re-warming simple foods (e.g., pies), the traditional female cooking role was difficult to overcome; this created gendered pressure on technology that resulted in microwaves being heavily re-conceptualized and re-designed to target women [35]. Such potential impacts highlight the importance of considering gender when designing robots and robotic interfaces. In this paper we advocate for a gendered approach to HRI, and aim for increased understanding of how gender may influence perceptions of robots, placing HRI practitioners in an improved position to predict, accommodate for, and leverage gender effects in their robot designs.

Despite the importance of gender, women are chronically under-represented in science and engineering (and thus the robotics and HRI communities): in the US in 2011 women made up only 20.8% of computer programmers, 19% of software engineers, and 13% of engineers [44], with the percentage of women with a computer science bachelor's degree dropping (28% to 18% during 2001-2009 in the US) [33]. Men are much more likely to be technology designers while women are more often technology users only [1, 7]; women are under-represented even in domains where they are the primary users [30]. This emphasizes the need for HRI-specific gender studies, as there is an increased likelihood that women's interests will not be properly considered, which can impact technology success: for example, male-dominated "smart house" project teams focused more on centrally networking entertainment and security appliances and did not properly (some not at all) consider women's interests, a limitation directly linked to poor product success [6]. To avoid similar pitfalls for HRI, we must develop and promote gender sensitivity within the community, as well as design methodologies to help robot and interface designers maintain awareness of such issues.

We present a gender-studies foundation for HRI that advocates for and frames an inclusive approach to research and design to include and consider both women and men's needs. Further, we present the results from an exploratory study that, in addition to providing insight into how women and men view robots in society, highlights how differences between men and women's opinions are much more nuanced and complex than common "pink" versus "blue" simplifications; for example, while both discuss similar issues (such as potentially diminishing human-human interaction), there were marked differences in how issues were discussed and concerns were framed.

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GENDER-STUDIES FOUNDATIONS FOR HRI

Gender studies (or: feminism, women's studies, or men's studies) uses gender identity or sex as a central theme of research investigation [17] and is commonly used to investigate science and technology, for example, to ask how gender fundamentally shapes how technologies change and develop [21], affects technology adoption and use [47, 48], or how not considering gender can limit technology [1, 6].

Some may feel that robots, and the underlying technology and algorithms, are gender neutral, or that astute practitioners can stay objective and do not need to consider gender when designing and building robots (this has been discussed in relation to HCI [38]). However, people cannot escape their own gender identity, which heavily impacts their work and decisions: people themselves, and all their interactions, are embodied within and therefore fundamentally impacted by their body and social identity [22, 54] (which, in science and technology, is usually male). We agree with Haraway [28] that the "god trick" of staying perfectly objective (seeing the world untainted by, or from outside of, one's own existence) is impossible, and practitioners thus must consider how gender relates to their decisions. This perspective highlights how HRI and robotics (and technology in general [16]) are already gendered, and it is important to consider how to move forward to re-gender the field in a more balanced way.

Thus it is important to explicitly consider both men and women as distinct user groups, as they have unique physical, social, and psychological properties and needs; this *gender sensitivity* to both men and women can help practitioners. On the flip side, a hazard of gendered design is a possibility of forming overly-simplistic categories and representations to differentiate women and men. Simplistic *binning* into rigid groups can be dangerous and can lead to identifying, and re-enforcing through design, possibly harmful stereotypes. For example, early assumptions about driving being a male task (a simplistic categorization of men and women) lead to car safety testing primarily targeting the on-average larger male [9] and ignoring the physical properties of women. This resulted in women being more likely to be injured or killed in car accidents [9], unfairly furthering a stereotype of women as bad drivers. Similarly, rigid categorizations of boys and girls result in "pink" versus "blue" toys that can reinforce stereotyped gender roles by shaping early childhood experiences. Therefore work in HRI must explicitly consider men and women's differences and needs for informing design, while at the same must avoid simplistic categorizations of male and female users. As postulated by *difference feminism*, we can accept that women and men may have different needs and preferences but should aim for enabling and inclusive solutions [40].

The gender-inclusive approach to design is a direct attempt to avoid the opposite, designs that exclude and disable; for example, through toy design, marketing, and social forces, boys may be discouraged from playing with "pink" doll and house toys. Rather, designs should, as much as possible, integrate the needs and characteristics of both sexes without excluding either [3]. In many cases, this inclusion is also a win for the majority group, for example, men would appreciate smart homes that help with domestic chores (considered by teams a woman's domain), and smaller men will benefit from cars also safety designed for women. This *inclusive design* goal is unfortunately not trivial to implement, but at the very least, this discussion highlights the need to examine how a particular robotic design may be inclusionary or exclusionary. Perhaps one successful example of inclusive robotic design is the iRobot Roomba, a robotic domestic vacuum cleaner: although cleaning is an established female domain, the high-tech image of the product (thus appealing to males) has improved the gender balance of cleaning in some households [25, 26].

Raising the profile of gender studies in HRI is not a substitute for more women involvement. Raising awareness alone has the danger of simply trusting (primarily male) practitioners' sense; for example, male-dominated design groups have been known to involve women by constructing knowledge about them and casting them as usability subjects, sometimes in a sexist light, without involving any women in positions of actual design influence [2]. Even with better representation, improved sensitivity to gender issues will still be important to promote fairness: for example, both men and women rate women academics more harshly than their male counterparts, both are often unaware of their own biases [40], and women will likewise benefit from sensitization to male issues [15].

One challenge of doing gender studies is that a person's gender identity, a social construct, cannot be adequately described by simple terms such as male and female. In fact, a person's gender may not necessarily correlate with their *biological* sex. Instead of attempting to address the complexities of gender, studies, like ours, generally use *sex* as a straightforward way to categorize people, as it serves as a coarse-grained sampling method which provides a metric of analysis roughly along the gender lines [47]. We highlight, however, that this is a serious simplification which does not address the true diversity and range of people, and rigidly categorizes people into bins in precisely the way we are arguing to avoid; future work will need to address the complexities of gender more deeply [38].

Moving forward it will be useful to have a sense of gender representation in HRI. As an initial step, we surveyed participant pools used in papers in the ACM International Conference on Human-Robot Interaction from 2006 (initial year) to 2013. Of the 190 papers with formal studies, only 106 (56%) provided sex, and within those, only 21 (20%, 11% overall) provided at least minimal or passing sex-based analysis. While we assume sex is not reported in most cases due to lack of awareness of the importance, if there is a link between gender-sensitive researchers and reporting, then unreported data may be less balanced. For the data available, women made up on average 44% of a study's participants (t_{105}=-4.425, $p<.001$, against expected

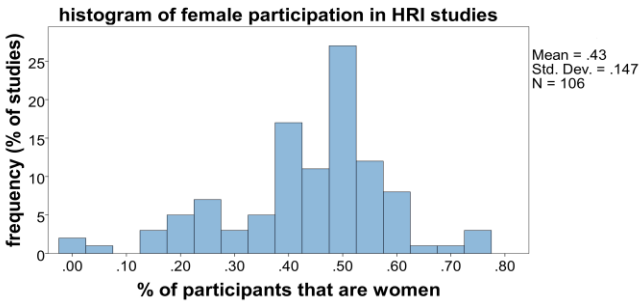

Figure 1 – Results from our literature survey on how sex is represented in HRI participant pools.

50%); although the distribution is in favor of more male participants (Figure 1), this result is quite encouraging as it shows that women are being involved in the HRI design process at the participant level. Further, this is more promising than the longer-term outlook at the ACM CHI conference which was much more heavily male oriented [4].

In summary, sex is inseparable from design and should be integral to HRI research. While the needs and unique characteristics of both women and men need to be considered, it is unfortunately still a small minority of HRI work that includes sex. When conducting work, rather than developing "horoscope"-style broad characterizations and perceptions of men and women (e.g., for "pink" versus "blue" robots), we argue for an inclusive approach that accepts that differences are rather more nuanced and complex. That is, we need to learn from both women and men to develop good designs that, as much as possible, fit the needs of both male and female users.

In the remainder of this paper, we detail related gender work to highlight both the importance of this direction and the lack of gendered HRI knowledge. We present a study that provides insight into how women and men may view robots in society, and through the process illustrate how sex differences may not fit simplistic categories.

RELATED WORK

Gender studies has explored how gender relates to science and a range of technologies such as the microwave [35], electronic banking [2], particle physics [45], even video games [13]; however, there has been less investigation with robots. The field of HRI exists alongside related areas of Human-Computer Interaction (HCI), psychology, sociology, etc., as robots are a unique technology that requires specific attention and entirely original methods and techniques [29, 54]. Likewise, existing gender studies methods should be re-examined and the field should be extended to consider gendered analysis of robots and HRI specifically.

Feminism research is becoming more strongly established in HCI, including a more recent theoretical focus on formulating problems and proposing how to include feminism in HCI [3, 38]. HCI has also explored how men and women use interfaces, for example, there are gender differences in exploration (e.g., tinkering vs. reference using [11]) and problem-solving strategies [5]. Software can be more likely to cater to male-typical interaction strategies [11], being easier to use for men and thus re-enforcing the problem of women having less technology self-efficacy (irrespective of ability) [55]. In response, research has been promoting inclusive design to reduce gender bias, for example, by addressing non-tinkering exploration styles (more common for women) [11, 27], or adapting immersive interfaces to also cater to women's needs [19]. We are hopeful that similar fundamental and inclusive design directions can be taken in HRI.

There has only been sparse HRI gender-studies work to date (e.g., as per the previous section), with most being afterthoughts instead of targeting gender specifically. For example, women and men may evaluate robots using different criteria such as task (men) or interactive behavior (women) [32], may have different preferences for being approached by a robot [20], or may perceive a same-gender robot as being more "psychologically close" and having more in common [24]. Initial results from recent work that targets gender indicates how women and men may have different needs from robots (e.g., for assistive technologies [12]) or may perceive robots differently (i.e., as social entities for men vs. as machines for women) [39].

The designed-in and perceived gender of the robot itself (in contrast to the person's gender) may also be important, for example, men may respond more positively to a female robot than a male one [42], and human-gender stereotypes may apply to robots and impact their perceived personality (e.g., harmless or friendly [51]), perceived knowledge base (e.g., on dating [37]) or reliability [18]. Some researchers investigate how this can be leveraged to impact interaction [23, 51] or discuss if such transfer of preconceptions is desirable [51]. This work shows how a robot's "gender" can be an important aspect of interaction; although related to our work, this is different than exploring the user's gender.

The state of gender studies in HRI is encouraging as fundamental research is emerging and some studies report gendered effects and analyses in their results. We extend this direction by providing a gender-studies foundation for HRI (above), and an instance of an analytical look at how women and men view robots' potential roles in society.

EXPLORATORY SURVEY

We conducted an on-line survey that explored attitudes toward robots in society, with the primary results indicating that women and men share opinions and concerns across a range of societal contexts. More relevant, our study serves as an example of the importance of sex analysis in HRI: we follow-up with a sex analysis that highlights important differences in how women and men respondents formed their opinions, differences which would have been missed without explicitly taking a gendered lens throughout.

Survey Design and Methodology

We designed our survey along two dimensions: we inquired about a range of robotic usage scenarios to provide broad coverage, and for each scenario we inquired on various aspects of attitudes (e.g., perceived risks, preferences, etc.).

The scenarios used (inspired by [31]) were: domestic (for security and housework), military (in battle or for risky jobs), education (to tutor), healthcare (surgery to personal care), entertainment (for fun), and urban search and rescue (for disasters, etc.). For each, we investigated: if people believe that such robots would become commonplace and if they feel that society should spend time and money on them, their perceived social risks or impacts, and perceived usefulness of the robot task (inspired by technology adoption predictors [46, 47]). We further provided concrete robot use-case examples to illustrate the scenarios, such as a sexual surrogate robot for entertainment or a bomb-disposal robot. Finally, we investigated robot-design (e.g., color, shape, etc.), but due to the limitations of study design there is a lack of results, and we do not discuss this further.

Questionnaire Design

The online survey first inquired about participant sex (see the foundations section), age, cultural background and exposure to robots. Respondents were then assigned to four of six robot scenarios (order counterbalanced); this shortened the study as pilots suggested that it was too long. The questionnaire was organized into units based on the robot scenario (e.g., healthcare robots, then education robots), and within each unit, participants answered the attitude-toward-robot questions using five-point Likert-like scales (e.g., from "very likely" to "not at all likely" that the respondent would adopt a certain robot) and open-ended comment boxes where they were encouraged to elaborate on their selections. Participants finished with questions on general attitudes toward robots irrespective of task via the Negative Attitude towards Robot Scale (NARS) [34].

To begin each unit we gave brief descriptions, for example, "Entertainment robots are designed to please their users… entertainment robots may sing, dance, play music, and do public performances. They may also play games with you, talk with you, be a pet, and so on." We designed these to be neutral and not leading (e.g., military robots did not encourage support or fear). Also, we decided not to use videos, pictures, or sketches of robots over concerns of how the specific robots may impact perceptions, for example, scaring participants with a menacing-looking large robot.

Methodology

We posted advertisements on web boards and mailing lists around North America, and placed posters around our university campus. No compensation was provided, and the survey took about 30 minutes. We received 118 valid responses: 46 female (39%), 72 male (0 intersex), aged 19-65 (M=29.97, SD=9.91), from 16 cultural backgrounds, primarily Canada (N=61), China (N=12), and USA (N=10). The underrepresentation of women is a problem (39%), but we mitigate this by treating both groups equally in analysis. Our respondents were well-educated (65% have/above bachelor degree), and 53% listed previous experience with robots, for example, owning a Roomba (the vast majority) or having interacted with robots in museums or at schools.

Qualitative Results

We used affinity-diagram-assisted open and axial coding to reveal prominent themes regarding robots entering society. Our analysis revealed that women and men tended to discuss similar broad issues and share general opinions on robot development; these issues fell into general themes that we present below, which do not align with the questionnaire's scenarios. We follow this data with a sex-based cross-analysis of these themes to provides insight into how sex may impact adoption of and interaction with robots.

Quotes are annotated with W (woman) or M (man) with participant number and age. We do not provide percentages or counts of groupings as we believe this would detract from the exploratory and illustrative purpose of the work, and so we generalize to broad terms such as "many" or "some" to reflect the general commonality of feedback.

Robots Helping In Personal Lives

Respondents discussed how robots could help them in their personal lives by performing menial, routine tasks, for example, domestic or healthcare robots:

> *"If I develop some sort of condition that requires … reminding me to do something or measuring something simple then I can imagine a robot could do it." – W20 (33yrs)*

> *"Household chores are a burden that I would thankfully delegate to a capable robot." – M42 (30yrs)*

Although some female participants did mention that they may still prefer to do the work by themselves:

> *"It would be convenient to have a [domestic] robot that could perform those tasks for me, but I would still prefer to do it myself." – W9 (22yrs)*

Female participants were much more likely to frame such benefits as an enabling force in their personal lives:

> *"[domestic utility robots] give me a bit more time to do other things, like personal projects or hobbies" – W109 (22yrs)*

and to emphasize opportunities to spend quality time with friends and family:

> *"While robots are doing housework, I can get so many different tasks done. I can use the time with family and friends instead of doing the housework." – W10 (34yrs)*

Whereas male respondents more generally framed benefits in terms of their work or general benefits to society:

> *"…can concentrate on my work if there are the robots in my life because I really do not need to care about housework at all." – M35 (29yrs)*

> *"There is also a use in companion use for the elderly and vulnerable, like the robotic seal currently used in retirement homes." – M34 (25yrs)*

Overall, male respondents were much more enthusiastic about benefits and provided significantly more feedback, such as how robots may help with education:

> *"Educational robots might attract children and may help them learn stuff in an effective manner." – M47 (28yrs)*

and entertainment robots in particular received a great deal of enthusiasm from men:

> *"Entertainment Robots could be very entertaining. The unpredictability of these 'bots' would be the fun, I would*

think." – M37 (20yrs)

whereas many women expressed a direct lack of interest:

"I'm done with school. I can't think of a way that Educational Robots could affect my life." – W15 (29yrs)

"Entertainment robots are useless, and people already have a lot of ways to entertainment." – W116 (29yrs)

However, many did indicate willingness to adopt, given social pressure:

"I think I have enough technology to keep me entertained. However, I suppose if these became ubiquitous, I would consider purchasing one." – W2 (42yrs)

While both women and men respondents were interested in how robots could aid daily life, there was a difference in enthusiasm and interest between the groups. Further, male respondents were more likely to show interest for benefits to broader society, while women expressed more interest close to their own homes and personal lives.

Saving Lives

Participants were very positive about the potential for robots in high-risk jobs to offer protection and save lives:

"Military robots may make our country more secure and protect us from bad guys." – W116 (29yrs)

"In case of an accident I would think that a [urban search and rescue] robot could save lives." – M36 (37yrs)

Both groups talked about saving the lives of soldiers, although women were much more likely to frame this in terms of their own social network:

"I have family and friends in the military and if a robot can help protect lives that would be very positive." – W2 (42yrs)

while men more commonly talked about soldiers in society in general:

"Hopefully in near future I'm not going to hear soldiers were killed in battle, and that would make the world a lot more peaceful as it is." – M43 (23yrs)

Only men talked of the dangers of having robots in the military, such as war escalation:

"More fighting occurs; because people aren't being killed, why not fight more? The risk is less than it is with people. I think having people fight in wars creates a sort of deterrent…But with robots, I think there would be fewer questions about going to war." – M51 (32yrs)

or dehumanization of killing:

"People who control robots such as the predator unmanned planes may feel like they are playing a video game which removes them from the actual battle. This may increase the likelihood of firing their weapons than in a manned airplane." – M39 (33yrs)

Overall, men talked a great deal more about military topics than women did. In fact, some women explicitly stated their lack of interest in the topic:

"Military robots wouldn't impact me because I have no affiliation or interest in the military." – W9 (22yrs)

Similar to the previous theme, here men again expressed a greater interest in social impact of robots, and women were more likely to talk about benefits to themselves and their social networks, while men reflected more on broader society.

Danger from Technical Issues

Participants cited concern over a broad range of risks associated with potential robot malfunction:

"Robot does something wrong and breaks things." – W20 (33yrs)

"For some tasks such as taking a pulse, need to ensure appropriate fail safes to ensure that the correct reading is indeed being taken, otherwise it could lead to potentially deadly scenarios." – M34 (25yrs)

For risks, women focused more on the autonomous abilities, such as powerful artificial intelligence or cold logic:

"Robots become stronger/more intelligent than humans and we can't control them." – W10 (34yrs)

"They are not emotional or logical, they are controlled by program or person or a system." – W3 (41yrs)

whereas men talked more of specific mechanical issues such as an out-of-control robot or protecting private data:

"Keep them always controlled by humans! On/off switch, emergency switch, etc.!… Never allow them to access or forward personal information. Make them highly secure to their owner!" – M85 (50yrs)

Overall, women were more likely to discuss risks in terms of potential impact to themselves and their social circles:

"I am thinking about a robot … fencing with me and hurt me because a failure in the system…for instance, what comes to my mind is an uncontrolled malfunction." – W29 (24yrs)

while men more often discussed general societal impact:

"Malfunctioning [healthcare] robots could lead to improper treatment and could possibly lead to unnecessary deaths. – M87 (27yrs)

While many respondents talked about the risks due to technical issues, a difference emerged in how this concern manifested in women and men: women were concerned about the unknown intelligence within the machine, while male respondents showed more worry over face-value technical issues such as breaking components. Also, as with the previous themes women were more likely to relate to themselves and their personal social circles while men reflected on broader societal issues.

Robot Performance and Capability

Respondents expressed concerns over robot performance quality in a range of application areas:

"Anything to do with my health I don't see myself trusting a robot to do what a human can do manually." – W118 (21yrs)

"I don't really trust any programed device to work in the near future." – M52 (57yrs)

Much of this discussion was about the idea that humans have capabilities that robots could not possibly perform:

"There is a human-judge-ness factor or human-perception sort of think that I don't think [domestic] robots are able to make." – W15 (29yrs)

"Good human teachers and tutors can make the students understand complex matters and issues better, which might not be the case with Robot teacher." – M47 (28yrs)

As with above, women's discussions were primarily considering healthcare and domestic applications:

> *"Losing the advantage of human perception. Doctors and nurses will often notice other conditions just by observing the patient. A [healthcare] robot couldn't do that." – W4 (25yrs)*

> *"The job isn't completely well done and I have to redo parts of it [Roomba: a vacuum machine]." – W20 (33yrs)*

while male respondents talked little about these and more about education, search and rescue, or the military:

> *"It would be impossible to account for the various search and rescue scenarios, so there would be a danger of a failed rescue further harming the victim." – M62 (24yrs)*

Men and women both had concerns over robot performance, but there was a clear separation of which application domains women and men reported their concern over.

Emotional Needs

Respondents expressed concern about whether robots could meet people's emotional needs, primarily in healthcare:

> *"When I'm in the Emergency Room, I want a Human to be treating me, not a robot … a robot could not possibly be comforting enough. People want to talk to other people about their health concerns." – W15 (29yrs)*

> *"if they [healthcare robots] do not have some sort of 'emotion' or 'empathy' programmed to them, it'll be crap. Patients tend to get support and caring from their nurses/therapists, if they are just cold machines, then there's no point." – M63 (23yrs)*

although emotional needs were more heavily discussed by women and very little by men:

> *"If I had a heath condition that I couldn't have a pet, the robot will be a companion and I can see that will be fun" – W10 (34yrs)*

Not only was this concern primarily reported by women, as in the above examples, women more often wrote in terms of themselves or their social network (e.g., using words such as "I" or "we") while men talked about people in general.

Impact on Jobs

Many respondents cited potential negative impacts on the job market, with particular sensitivity around people who felt they themselves may be replaced:

> *"They could replace nurses and then I would have gone to school for nothing." – W105 (21yrs)*

> *"I teach. I would not adopt robotic assistants for several reasons. First, I do not like computerized teaching methods…. Second, people need to work and replacement of people with robots will have a serious impact on quality of life. Industrialization of intelligence is not a uniformly good idea." – M45 (36yrs)*

This was much more heavily discussed by male respondents, who wrote a great deal about broader economic impacts and the surrounding social issues such as who would lose their jobs, a topic barely breached in female feedback:

> *"Replacement of the current human beings in those positions could lead to unemployment rates jumping in middle class (Nurse, nurse aids)." – M75 (25yrs)*

> *"These robots [domestic robots] will make people lazier as well as take away easy jobs that uneducated people could do." – M75 (25yrs).*

Thus while respondents of both sexes indicated concerns over jobs, male respondents much more commonly related these concerns to the broader social and economic picture beyond their own jobs.

Erosion of Human Interaction

A common concern discussed was that having robots would reduce human-human interaction:

> *"A robot is not a real human, it feels unnatural for me to interact with something that isn't real. Even if it's just a toy, I prefer to play with a real dog and talk to a real human." – W9 (22yrs)*

> *"actual human-human contact may be reduced if [entertainment] robots replace partners" – M36 (37yrs)*

and respondents cited a range of potential negative impacts from this, such as a detriment to social skills. Women respondents talked broadly about this issue:

> *"risky, people forget how to interact with people" – W10 (34yrs)*

> *"If a person spends lots time with robots, he may have less time with people, it's not good for their communication with others." – W25 (24yrs)*

while male respondents tended to focus heavily on how this may impact children's growth and development:

> *"[Educational robots] Lack of good emotional perception and feedback will fail to teach young children good social skills." – M58 (40yrs)*

> *"Younger kids might become apathetic in nature and grow up in that way." – M47 (28yrs)*

Again, as with the previous themes, here we can see that our male respondents were more likely to apply their concerns to a broader social context.

Quantitative Results

We applied the Linguistic Inquiry and Word Count tool [36] to analyze our text, for example, for social, affective, work, leisure, money, etc., concerns. The men (Mean=4.48% of words written) used positive-emotion words more than women (M=3.30%, U=867.5, z=-1.939, p=.052, r=-.20), and women (M=0.22%) used family related words more (M=0.07%, U=907.5, z=-2.544, p=.011, r=-.26).

The open-ended questions were accompanied by Likert-like scales: we used non-parametric tests as data was not normal (Kolmogorov-Smirnov tests, $p<.05$). *All* participants had missing data (assigned 4/6 categories), prohibiting the use of non-parametric repeated-measures omnibus (ANOVA-style) analysis; thus we performed pairwise (men versus women) Mann-Whitney tests across the data. Statistics are summarized in Table 1 for readability.

Men (Mdn=2) were more supportive of domestic robots being developed than women (Mdn=2), while women (Mdn=4) regarded adopting domestic robots as more "risky" than men (Mdn=4). Men were more positive (Mdn=2) about entertainment robots (women Mdn=3), and their potential for impact (men Mdn=2, women Mdn=3), while compared with men (Mdn=4) women (Mdn=4) reported that entertainment robots have more risks to society and personal risks (men, Mdn=5, women, Mdn=4).

Question	Fem.	Male	U	z	r
should develop domestic robots (1 definitely should, 5 definitely should not)	2(+)**	2(-)	475	-2.84	-.32
adopting domestic robots is risky to personal life (1 very risky, 5 not at all risky)	4(-)**	4(+)	501.5	-2.67	-.30
should develop entertainment robots (1 definitely should, 5 definitely should not)	3***	2	401.5	-3.08	-.36
impact of entertainment robots (1 very positive, 5 very negative)	3*	2	499.5	-2.08	-.24
adopting entertainment robots is risky to society (1 very risky, 5 not at all risky)	4(+)***	4(-)	389	-3.28	-.38
adopting entertainment robots is risky to personal life (1 very risky, 5 not at all risky)	4***	5	371.5	-3.48	-.40
sex robot is useful (1 very useful, 5, not at all useful)	4*	3	449	-2.54	-.30
consider buying a sex robot (1 very likely, 5, not at all likely)	5(+)*	5(-)	508	-2.05	-.24
would feel nervous operating a robot in front of other people (1 strongly agree, 5 strongly disagree)	4(-)**	4(+)	1153.5	-2.75	-.25
If I depend on robots too much, something bad might happen (1 strongly agree, 5 strongly disagree)	2*	3	1235	-2.41	-.22
I feel that in the future society will be dominated by robots. (1 strongly agree, 5 strongly disagree)	3*	4	1305	-2.00	-.18

Table 1. Summary of significant results on attitudes toward robots from Mann-Whitney tests, median reported and denoted by (+) larger and (-) smaller based on mean ranks when necessary. * p<0.05, ** p<0.01, *** p<0.005

The only specific robot type with significant effects was sex robots: men (Mdn=3) reported them as being significantly more useful (women, Mdn=4), and men (Mdn=5) were also more willing to acquire a sex robot (women, Mdn=5).

Overall across robot categories, women respondents reported being more nervous to operate a robot in front of others (Mdn=4, men Mdn=4), being more concerned about depending on robots (Mdn=2) than men (Mdn=3), and about robots dominating society (Mdn=3) in the future than men (Mdn=4). No other significant effects were observed.

SEX-BASED ANALYSIS OF RESULTS

Overall, our male and female respondents tended to discuss similar broad issues and share general opinions on attitudes toward robot development. Looking deeper into participant feedback, we can see important nuanced differences in terms of how opinions were formed and discussed, differences which can perhaps provide insight into how a person's sex may impact adoption of and interaction with robots. For example, throughout our data men were more positive toward robots overall than women, and men had a more economic focus than women. This follows a well-documented rough pattern of gendered differences in technology acceptance [41, 52]; however, our results go beyond simply identifying this difference and provide insight into some of the underlying reasons. In the remainder of this section we detail our analysis.

Both groups expressed a range of potential benefits as well as a great deal of doubt over robots' actual abilities to perform tasks, but there was a marked difference in the kinds of reasons and tasks that respondents mentioned: women more commonly framed their discussion in terms of impact on their personal lives and social networks while men talked more of broad societal issues. This supports a previous result that found that women may talk more about personal topics while men may talk more about public topics [50]; we discuss and unpack this further below.

Female respondents were much more likely to care about personal everyday life aspects such as how robots may impact or improve quality of life for themselves and their family, for example, more freedom if robots do housework. They also expressed clear interest in comfort or human-like issues of interaction such as how caring a healthcare robot could be or if robots would be "natural" to interact with. In addition, examples by women (both negative and positive) were usually framed in terms of impact on themselves and their social network, for example, if robots could protect lives of friends and family in the military, or provide them with free time to spend with their social network.

In contrast, male respondents expressed more concern over broad societal issues such as impact on jobs, war escalation, or impact on children in general, and used more general language in contrast to the female respondent's precise social network references: for example, "soldiers" instead of "family and friends in the military." This difference was further echoed in our linguistic analysis where women used more "family"-oriented words than men. When talking about themselves, male respondents more commonly expressed, for example, benefits to work instead of family.

This difference in how people may evaluate robots echoes other HRI findings which suggest that women may care more about interactive behaviour while men may care more about task [32]. Further, in comparison to prior work that found that women may focus more on social impact while men focus more on the technology itself [10, 47], our results paint a more dynamic picture in relation to robots that includes various task domains and levels of interest (personal, broad societal, etc.)

Part of the personal-versus-societal difference may be a reflection of men having more technology self-efficacy than women, regardless of ability [11]: perhaps men may be more confident and egocentric to provide broader opinions while women may simply be more reserved. This self-efficacy disparity may also explain our finding of men in general being more positive toward robots than women, an observation that mirrors existing work that suggests women perceive more risk than men in making decisions [11, 43].

However, if we abandon the labelling of women as being somewhat technophobic to explain the results, our data instead points toward an issue of relevance. Female respondents quite clearly discussed robots in terms of immediate benefit to them in their daily lives and abilities to cater to their social and emotional needs, including

comfort issues such as appropriate social interaction. In contrast, many women directly discussed a lack of interest in robots and a perception of irrelevance, much more commonly than exhibiting "techno-fear" as postulated above. We believe that this may relate to a broader issue of perception of robots, which are commonly portrayed in media as factory workers, military aides, space-exploration machines, or cold mechanical tools (e.g, a vacuum cleaner), and much-less commonly portrayed in contexts that highlight their social characteristics (e.g., as guides in museums or companions in hospitals). At least for our female respondents, such characterizations may simply not appeal to their sensibilities and family-oriented priorities, and may align much more closely to the discussion points of our male respondents. This explains our results clearly and does not involve techno-fear. Thus, we believe that moving forward it may be helpful to focus on priorities and perceptions of robot relevance from a gendered perspective to help garner interest and willingness to adopt.

This study not only detailed a broad view of women and men's attitudes toward robots in society, but also revealed a range of sex-based nuances that provide insight into how people may perceive and understand robots. Overall, the results point to the importance of considering sex (and thus, gender) in HRI research, and demonstrated our call for inclusive investigation that aims to describe and understand women and men rather than construct simplistic gendered categories; in this case, although women and men agreed in general on issues surrounding robots in society, we showed how there were more subtle, important differences.

LIMITATIONS AND FUTURE WORK

This paper provided a gender-studies foundation for HRI and presented initial results that highlighted nuanced gendered perspectives on robots. The problem remains of creating concrete tools and guidelines for researchers to leverage to aid them in gender work. However, this task is quite dangerous as any rule adds the risk of entrenching stereotypes. Thus any such future direction should focus on inclusive and sensitizing principles. We believe that an important way to approach this problem is to have ongoing qualitative investigations of actual robot users, focusing on gendered differences, to help detail and build understanding.

Our broad study design enabled us to explore, but at the cost of limited detail for any type of robot. For example, we covered only a few aspects of domestic robots while this in itself could be a rich area for study. In addition, it may make sense, particularly as more robotic products enter the market, to focus more on a specific area such as domestic or workplace robotic assistants.

One important limitation of our work is our simplification of gender into rigid sex categories. A person's gender does not fit cleanly into "man" or "woman," which raises the danger of our study overlooking important differences between groups not identified by our limited classification scheme. As it is, we believe our work provides useful sensitizing information for HRI researchers with sex as a sampling method, but moving forward it will be important to re-evaluate our conceptualization of the groups and to investigate a more diverse representation of gender.

Our results have pointed out a great deal of ideas for more targeted analysis, for example, that men may have more interest in robots for children or women may care more about healthcare robots. We hope the field will continue to help map gendered perceptions and ideas around HRI.

CONCLUSION AND RECOMMENDATIONS

In this paper we explored how women and men view robots, and how gender relates to the challenges of HRI. We presented the argument of why gender permeates HRI and cannot be ignored for robot design, and presented a qualitative exploration of how women and men discuss various aspects of a range of robots. This discussion highlights how sex-nuanced even simple opinions on robots can be, and hopefully can help develop gender sensitivity in the field. This gender-studies foundation also helps to frame why productive and inclusive gender studies work should take place, and why potentially harmful stereotype-entrenching approaches should be avoided. Bringing our findings together, we propose the following guidelines for gender studies in HRI:

Gender Sensitization – Aim to develop sensitization to and raise awareness of gender and related issues, as gender is important for robot development and HRI.

Inclusive Design – Gender studies in HRI should aim to understand all users (both women and men) and include their needs and preferences in design, rather than looking for rigid female versus male guidelines or versions. Be wary of exclusionary "pink" versus "blue" design which can re-enforce existing stereotypes.

Relevancy of Robots – We found evidence that robots may appear to be more relevant to men. Moving forward the field of HRI should attempt to counter this by highlighting benefits for all users and not just dominant domains such as the military or search and rescue.

Beyond Utilitarian Task – HRI has been developing social interfaces that move beyond utilitarian task and include, for example, user comfort or natural interaction with robots. Gendered nuances in this direction should be explored, as it may be more appealing to women users.

Overall, we envision that this work can be a step in improving the profile and visibility of gender studies in HRI, and serve as a spring board from which other gender studies can build from. We hope that this direction continues to grow and that ultimately researchers can work together to aim for inclusive, enabling design for all users.

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