Gendering Human-Robot Interaction: Exploring How a Person's Gender Impacts Attitudes Toward and Interaction with Robots

by

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Abstract

Previous work presented that a person's gender is an important factor in shaping how new technologies are adopted and used. Further, a lack of awareness of gender issues increases the risk of technology rejection and misunderstandings. Therefore, considering the development and adoption of robots, it is crucial to develop an improved understanding and awareness of what role gender plays in the field of human-robot interaction (HRI). In this work, we aim to investigate how a person's gender impacts how they perceive and interact with robots.

One problem is that we have limited gender-related knowledge as only a few gender issues have been targeted in HRI. To get a rounded understanding, we tackle our research question with a three-pronged approach: 1) review of the general field of gender studies to develop a theoretical grounding for gender studies in HRI; 2) survey of perceptions of robots in various usage instances from a broad perspective to get an initial view of how a person's gender impacts their attitudes toward robots; 3) observation of the human-robot interaction in a controlled setting to contribute to the knowledge of how a person's gender affects their interaction with robots.

As an initial exploration, we expect our results to provide a theoretical grounding for why gender is important to consider for HRI, and to contribute to the understanding of how gender influences attitudes towards, and interaction with, robots. We hope that our studies serve as a source and foundation for future gender-studies, and motivate the need for gender studies in the HRI field.

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Publications

Some ideas and figures in this thesis have appeared previously in the following publication by the author:

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Chapter 1

Introduction

Advancing robotic technology and research promises that robots will continue to enter a range of personal spaces and contexts, for example, in homes as advanced toys, cleaners, companions, or medical assistants, in classrooms as tutors and teachers, or even utilized in hospitals as nurses and surgeons [43, 57, 63]. As such, the investigation of the surrounding sociological questions of how these robots will integrate into the world, and what this means for robot and interface design, has been an important component of human-robot interaction (HRI) research [63, 75]. One aspect remaining unclear is how a person's gender plays a role in this social integration and what this means for HRI design, such as how gender affects interaction with robots.

Work in gender studies has highlighted how technology and gender are inextricably linked. For example, previous research showed that a person's gender impacts how technologies are developed [14], used [68], and understood by society [3]. Further, the gender-technology relationship is not simply a static result of study [7, 69], but is rather an ongoing complex "process." For instance, the microwave oven was originally designed as a male bachelor technology for warming pre-cooked meals, but the traditional female role on the cooking was difficult to overcome, and actual use re-conceptualized the microwave as a female-targeted technology purchased by housewives to assist with cooking [13]; existing gender roles induced a re-design of the microwave. Overall, the interconnected nature of social forces, especially gender roles and technologies highlight the importance of considering gender when designing robots and robotic interfaces. By improving our understanding of how gender may affect people's interaction with robots, HRI practitioners will be in a better position to predict, accommodate for, and even leverage such gender effects in their robot design, and to make better-informed and responsible decisions regarding how their robots may impact society.

Women are chronically under-represented in science, technology, and engineering. Men are much more likely to be technology designers while women are more often technology users only [7] – in 2011, women made up only 13% of engineers, 20.8% of computer programmers, and 19% of software engineers in the US [65]. Further, the percentage of women with a computer science bachelor's degree dropped from 28% to 18% during 2001-2009 in the US [46]. The dangers of under-representing women's needs in science and technology are very real: for example, male-dominated "smart house" project teams focus more on centrally networking entertainment, energy, communication, and safety appliances, but rarely consider the traditionally-female domain of housework [6]; a study concluded that women's needs were generally not included in the "smart house" design process, a limitation directly linked to poor product success [6]. This emphasizes the need for HRI-specific gender studies: women are, statistically speaking, disproportionately excluded from science and technology and thus the robotics and HRI communities, increasing the likelihood that women's interests are not properly addressed or well considered. To help avoid the same pitfall for HRI, we must develop gender-sensitive knowledge that can assist designers.

In this thesis, we present the three-pronged approach that we used to improve the understanding of the impacts of gender in human-robot interaction. Due to the exploratory nature of our study, our main research goals involve: 1) building gender-studies foundations for HRI, 2) gaining an initial overview of men and women's perceptions of robots, and 3) probing men and women's differences in their attitudes toward and interaction with a real robot.

1.1 Methodology

Aiming to have well-rounded initial insights into gender in HRI, we take a multi-faceted exploratory approach. To help map out the broad area and develop a theoretical grounding for gender studies in HRI, we reviewed foundational gender studies concerned with technology development and adoption, and surveyed the current status of gender studies in HRI. To get an overall sense of how men and women perceive robots, we conducted an on-line survey of general attitudes toward robots in different usage scenarios (e.g., perceived usefulness, robot physical design, etc.). We also ran a laboratory study with a real human-robot interaction scenario, with the purpose of learning how a person's gender affects how they perceive and interact with a real robot. In this section, we briefly describe how we tackled our research problems from these three perspectives.

1.1.1 Building Gender-Studies Foundations for HRI

Given the limited gender-related knowledge in HRI, we started our exploration with building a theoretical grounding for gender studies in the field. We reviewed the literature in the general field of gender studies and identified the importance of gender for the development of general technologies. Then we applied the knowledge to explain how this is relevant to HRI and what goal gender studies should set. We also surveyed the current status of gender representation in HRI. (Chapter 3)

1.1.2 Exploring Men and Women's General Attitudes Toward Robots

To get an initial glimpse of men and women's general attitudes toward robots, we conducted an on-line survey [42, 62] that covers a broad range of issues related with robots, such as robot development and robotic impacts on society. The survey contained closed and open-ended questions.

We recruited volunteers via on-line advertisements and physical posters. Then we employed statistical methods and open coding qualitative analysis on the data. This study helped us learn how differences between men and women' attitudes toward robots are nuanced and complex, which further confirmed the importance of gender-oriented research in HRI. (Chapter 4)

1.1.3 Investigating Gender Differences in Perceptions of and Interaction with A Robot

In the exploration of how a person's gender may affect their interaction with robots, we conducted a laboratory study including human-robot interaction. This study enabled us to observe people's real-time attitudes toward robots during the interaction. It also provided us with an opportunity to explore how a person's gender and a robot's perceived gender are associated with perceptions of the robot.

Participants were recruited from our university population. We acquired data from questionnaires and researchers' observations of subjects' reactions to the robot, and then employed statistical analyses. Overall, our novel approach (verbal gender cues) successfully indicated the robot's gender. However, we failed to find differences between men and women when they apply social knowledge (e.g., gender stereotypes) to perceive and interact with our robot, which disagrees with previous findings. This conflict implies that more gender-oriented research is needed to update the knowledge of the impacts of gender in HRI. (Chapter 5)

1.2 Research Contributions

Contributions of this thesis are as follows:

- Gender-Studies Foundations for HRI – We motivate the needs of gender-related research, point out the ultimate goal of this type of work, and present the current status of gender studies in the field.

- Suggestions for Gender Studies in HRI – We provide a set of suggestions to robotic researchers based on findings observed in our studies.

- Exploratory Approaches – We use an on-line survey and a laboratory study to tackle our research questions from multiple perspectives. Our study designs and exploration approaches could be referenced by some future gender-related research in HRI.

- Gender Differences – We reveal some subtle differences in men and women's attitudes toward and interaction with robots.

Overall, we envision that this work can update the knowledge of possible gender effects in HRI, and provide a source and foundation toward developing gender-sensitive robot design guidelines to help robot practitioners consider both men and women's needs and preferences in the robot design process.

The rest of this thesis is organized as follows: in Chapter 2, we provide a review of the related work regarding our explorations. Chapter 3 presents our gender-studies foundations built on the literature in fundamental gender studies and a survey of gender representation in HRI. Chapter 4 details our on-line survey design and the results from comprehensive analyses. In Chapter 5, we describe the in-lab exploration that investigates the impacts of gender on people's perceptions of and interaction with a robot. We conclude the thesis in Chapter 6.

Chapter 2

Related Work

As computers and computer-related technologies permeate every aspect of our daily lives, Human-Computer Interaction (HCI) becomes a field that studies the interaction between people and computers regarding the physical, psychological and theoretical aspects of this process [23]. A sub-component of HCI is Human-Robot Interaction (HRI), which focuses on understanding, developing and evaluating robots for people to interact or work with [34]. One important aspect of HRI related to our work is social human-robot interaction [74], which deals with the influences of social factors (e.g., culture [5], gender stereotypes [26], etc.) on HRI. In this thesis, we aim to gain knowledge of the impacts of gender on how people perceive and interact with robots socially. Below we review some existing gender studies in Sociology, HCI and HRI, and relate them to our work. We end this chapter by discussing why previous work is not sufficient and how we plan to explore our research questions.

2.1 Gender-Related Investigation in Sociology

Gender studies (or: feminism, women's studies, or men's studies) uses gender identity or sex as a central theme of research investigation in general [18]. In sociology, gender-related work concentrates on the issues of how gender relate to their environments that they occupy, for example, the spaces (e.g., cities around the world [29]), places (e.g., the household [53] or the workplace [10]), social structures (e.g., gender inequality [10, 28]), and so on. It helps to improve the understanding of the impacts of gender on both private and public environments. As a multiplicity of robotic systems starts integrating into various aspects of our society (showed in Chapter 1), how gender affects this social integration and what this means for robotic design and the field of HRI become a promising research direction.

There is a large amount of science-related gender research in sociology, which explores how gender relates to science and a range of technologies. For example, previous work has explored how male-dominant science fields shape technologies development (e.g., the smart houses [6]), investigated how traditional gender roles affect technology change and adoption (e.g., bicycles or microwaves [1, 48]), and examined how the gender division impacts technology revolution and use (e.g., electronic banking [3]). This type of work has addressed the possible effects of gender on technology development and has looked at how this can be leveraged in different contexts of society. However, robots are a unique form of technology that require special attention and entirely original methods and techniques, as robotics have strong real-world presences and can elicit an unprecedented attribution of anthropomorphism and zoomorphism from people in comparison to other artifacts [40, 76]. Likewise, existing gender studies methods should be re-examined, and the field should be extended to consider gendered analysis of robots and HRI specifically. As a result, our work focuses on investigating the impacts of gender on HRI from multiple perspectives with gender-oriented experiments and analyses.

2.2 Gender Studies in HCI

Feminist research is becoming more strongly established in HCI, including a recent theoretical focus on formulating problems and proposing how to include gender in the field [4]. Researchers have explored gender differences in how men and women interact with computers and software interfaces. For example, prior work suggested that men are more willing to tinker in problem-solving software than women in the context of testing and debugging spreadsheets [12]. One possible reason could be that software is more likely to cater to male-typical interaction strategies [12], being easier to use for men and thus re-enforcing the common phenomenon of women having less technology self-efficacy (irrespective of actual ability) [77]. In response, research has been looking at ways to meet women's needs, for example, researchers mitigated the performance gap between men and women by addressing non-tinkering exploration styles (more common for women) [12, 35], or adapting the size of immersive interfaces to also cater to women's needs regarding virtual environment navigation [21]. We are hopeful that similar fundamental and gender-related research can be taken in HRI. Therefore, as an initial step, we emphasize the importance of exploring men and women's similarities and differences in attitudes toward and interaction with robots in our research to improve the understanding of both men and women's needs in HRI.

2.3 Gender Explorations in HRI

There are few gender studies in HRI to date. Due to the special physical design (e.g., human-like or animal-like shape) of robots, some work indicates that the perceived gender of the robot itself (in contrast to the person's gender) may be an important factor to consider in HRI. For example, researchers find that men are easier to be persuaded by a female robot than a male one [58], human-gender stereotypes may apply to robots and impact their perceived personality [26, 72], or people speak more to a male robot (e.g., about dating norm [50]) or rate a male robot as being more reliable [19]. Some investigate how a robot's gender can be leveraged to impact interaction or discuss if such transfer of preconceptions is desirable [72]. Our work extends this direction by exploring how a robot's perceived gender is associated with people's perception of the robot, but more importantly, we primarily focus on investigating the potential influences of a person's gender.

Previous work implies that men and women may evaluate robots using different criteria such as task (men) or interactive behavior (women) [45], they may have different preferences for being approached by a robot [22], or people may perceive a same-gender robot as being more psychologically close and having more in common [27]. Initial results from recent work that targets gender indicate how women and men may have different needs from robots (e.g. assistive technologies for the elders [32]) or may perceive robots differently (i.e., as social entities for men vs. as machines for women) [54]. However, most of these results are secondary instead of being desired from targeting gender specifically, and do not focus on actual interactions between human and robots or provide insights into underlying reasons for observed gender differences. In our work we attempt to address all of these concerns: conducting gender-oriented experiments and analyses, involving an actual human-robot interaction, and aiming to learn a person's gender effects by observing gender differences and looking into behind causes.

Overall, prior work has documented the potential impacts of gender on the development of technology and has provided promising directions for gender studies, as well as presented the current state of gender studies in HRI. However, given the proliferation of robotics in society, this unique technology raises the need to extend the field by conducting gender-based analysis of HRI. Further, the limited gender-related knowledge in the field is mostly initial afterthoughts. Therefore, in this thesis, we use existing gender-related knowledge in or out of HRI as foundations, and extend this direction by providing an analytical look at how men and women perceive and interact with robots using data acquired from an on-line survey and an in-lab study.

Chapter 3

Building Gender-Studies Foundations For HRI

To commence our research and develop a theoretical grounding for gender studies in HRI, we reviewed the general field of gender studies in sociology. This literature review offered insights into why gender permeates HRI and cannot be ignored for robot development and design, and why productive and inclusive gender studies work should take place. We also surveyed the current gender representation in studies published in HRI, which provides an initial sense of the current status of gender studies in the field.

In the following section, we detail the results obtained from the literature review and the survey, and end the chapter with suggestions for gender studies in HRI.

3.1 Gender Studies Fundamentals and Approach

Previous work shows that gender is an important factor for science and technology development and adoption. For example, gender fundamentally shapes technologies change and development [13], people decide to adopt and use technologies differently [66, 68], and failing to consider gender can limit technology [2, 6].

When considering gender studies for HRI, some may think that robots, and the underlying technology and algorithms, are gender neutral, or that robotic practitioners themselves can stay objective and do not need to consider gender when designing and building robots. 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 [24, 76] (which, in science and technology, is usually male (showed in Chapter 1). Therefore we agree with Haraway [37] 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 [17]) 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 for HRI, because they have unique physical, social, and psychological properties and needs; this *gender sensitivity* to both genders can help practitioners become aware and fit men and women's needs in robotics design. On the other side, a hazard of including gender in design is a possibility of forming overly-simplistic categories and representations to differentiate women and men. Binning women and men into rigid groups is problematic as it can lead to simply identifying, and potentially re-enforcing through design, existing and 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 poor 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 [70]. 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 [55] instead of stereotype-entrenching designs.

The enabling 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 genders without excluding either. 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 as a traditional female domain [61]), and smaller men would 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 [31].

Raising the profile of gender studies in HRI is not a substitute for more women involvement in all levels of robotic design and engineering. 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 [3]. Even when better representation is attained, 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 [55], and women will likewise benefit from sensitization to male issues [15].

3.1.1 Gender versus Sex

One challenge of doing empirical gender studies is that a person's gender identity, a social construct, cannot be adequately described by simple terms such as male and female. Instead of attempting to address the various aspects of gender, studies often 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 [68]. Therefore, although a person's gender may not necessarily correlate with their biological sex, as an initial step, we take sex as a gender indicator in our studies. We will address its limitation at the end of the thesis.

3.2 Current Gender Representation in HRI

Moving forward it is useful to have an on-the-ground sense of gender representation in HRI. Therefore, we surveyed the participant pools used in all papers published 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 participant sex as one demographic information, and within those, only 21 (20%, 11% overall) provided some basic quantitative sex-based analysis. For papers that report the participant's gender-ratio, women made up on average 44% of that study's participants (t_{105}=-4.425, p<.001, against expected 50%); however, the distribution is in favor of more male participants (Figure 3.1).

If we assume that the researchers who have gender awareness pay attention to gender-related issues and gender-targeted analyses, the data presented above (e.g., only 11% HRI research included gender-oriented analysis) indicates the absence of gender sensitization in the field. In other words, lack of gender-related analysis in HRI may be due to lack of gender awareness in robotic design process, then the unreported gender-ratio could be more imbalanced. Therefore, although this result shows that women are being involved in the HRI design process at the participant

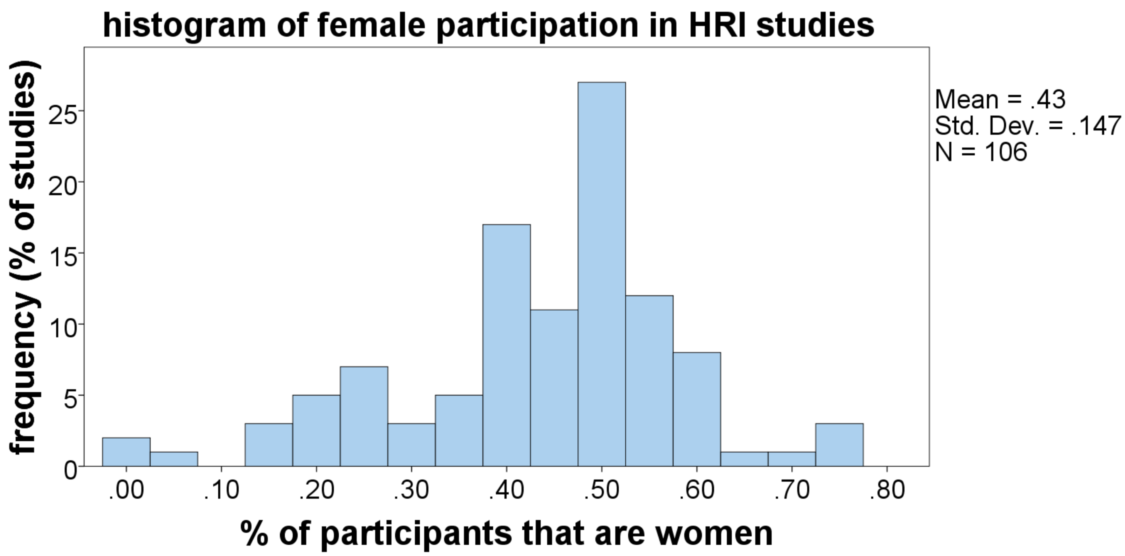


Figure 3.1: Results from the Survey on How Sex is Represented in HRI Participant Pools

level, there is a need to arise more researchers' attention regarding gender-related issues, and to promote gender-oriented exploration in HRI.

3.3 Summary

In this chapter, we presented the argument of how gender is inseparable from design and should be integral to HRI research. We also described the reasons for having productive and inclusive gender studies instead of harmful stereotype-entrenching approaches. Further, our original survey results provide an initial glimpse of the current state of gender studies in HRI. These three parts formed our initial gender-studies foundations for HRI. Based on it, we propose two recommendations for gender studies in the field:

Gender Sensitization – Robotic researchers should aim to develop sensitization to and raise awareness of gender and related issues as gender is important for robot development and human-robot interaction.

Inclusive Design – Gender studies in HRI should accept that gender differences are more complex than oversimplified gender stereotypes. Researchers should aim to understand all users (both men and women) and fit their needs and preferences in design, rather than looking for rigid female versus male guidelines or versions. They should also be wary of exclusionary "pink" versus "blue" design which can re-enforce existing stereotypes.

In this thesis, we focus on exploring gender differences in people's attitudes toward and interaction with robots, which may also help confirm the importance of having gender sensitization. We also expect the results to improve the understanding of men and women's similarities and differences in HRI, and to contribute knowledge toward the longer-term goal of building gender-inclusive design guidelines.

In the next chapters, we describe our studies that investigated men and women's general attitudes toward robots in society and gender differences in people's perception of and interaction with a real robot, along with the observed results.

Chapter 4

Exploring Men's and Women's General Attitudes Toward Robots Using an On-line Survey

To get an initial overview of the impacts of a person's gender on their attitudes toward robots in society, we designed and conducted an exploratory on-line survey to investigate people's perceptions of various robotic categories that are used in different contexts of society (e.g., hospital, school, military, etc.). For example, we collected opinions about robotic development, robotic physical designs, and so on. With qualitative and quantitative statistical analyses, the knowledge gained from this study reveals some gender differences in attitudes toward robotic development, and provides insights into how real-world gender differences on attitudes toward robots go beyond simplistic generalizations.

4.1 Study Design and Methodology

On-line surveys have been commonly used [42, 62] in place of empirical studies to achieve broad sampling of participants (age, background, culture, etc.) which may result in loss of sample control. However, due to the exploratory nature of our research, we chose to conduct an on-line survey that aimed for a broad multi-faceted sampling of people's attitudes. In this study, we aim at getting initial insights of gender nuances in people's attitudes toward robots instead of generalizing fundamental differences between men and women.

To broaden the survey, we asked respondents to consider robots from a range of perspectives and to think about the many possibilities for robots in society. We designed it along two dimensions: we inquired about a range of robotic usage scenarios to provide a broad coverage, and for each scenario we inquired on various aspects of attitudes (e.g., perceived risks, preferences, etc.). The scenarios used (inspired by related work [41]) were: domestic (for personal security and housework), military (in battle or for dangerous jobs), education (to help with study), healthcare (from surgery to personal care), entertainment (for fun), and urban search and rescue (for disasters, etc.). For each scenario, 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 tasks (inspried by technology adoption predictors [67, 68]. 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 for military. Finally, we investigated robot design (e.g., color, shape, etc.). Below are the details of how the questionnaire was designed and how we recruited participants.

4.1.1 Questionnaire Design

The on-line survey first inquired about participant sex, 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 the original survey, with all six scenarios, 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 completed 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) [47].

At the beginning of each unit we gave brief robot and scenario descriptions, for example, "Entertainment robots are designed to please their user. For example, 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 or large robot. The full questionnaire, with six types of robots, is shown in appendix A.1.

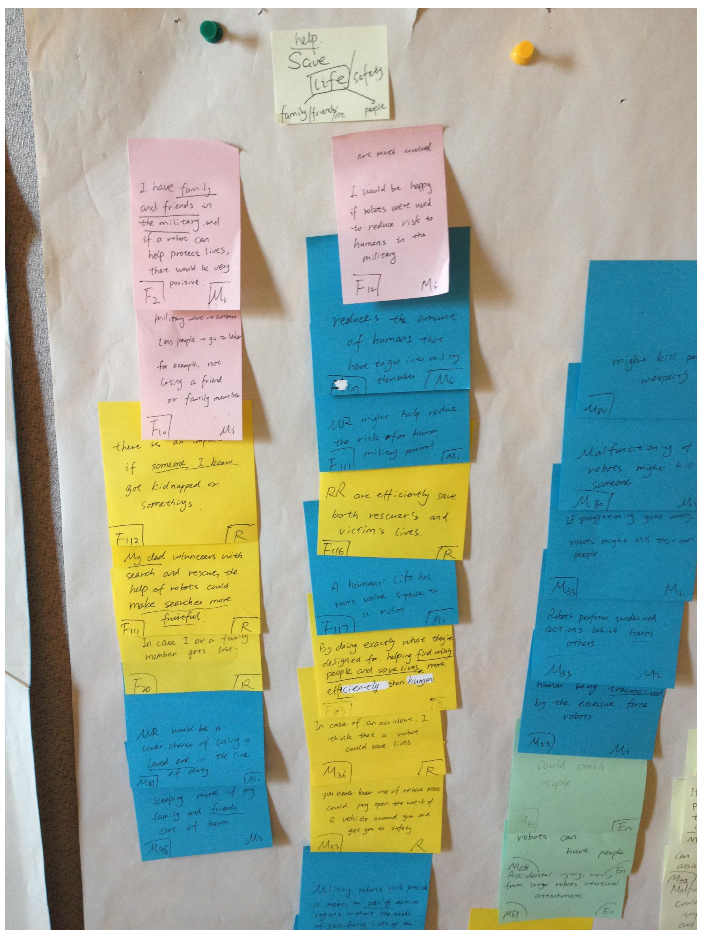
4.1.2 Methodology

We posted on-line advertisements on community web boards (e.g., kijiji, facebook, craiglist, etc.) and mailing lists around North America, and placed posters around our university campus. No compensation was provided for our 30-minute survey. We received 118 complete valid responses: 46 female (39%), 72 male (0 intersex), age range 19-65 (M=29.97, SD=9.91), from 16 cultural backgrounds, primarily Canada (N=61), China (N=12), and the USA (N=10). The under-representation of women is a problem (39%), but our gender-based analysis mitigates this by treating both groups equally, unlike in studies where no split is performed. 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. This convenience sampling method restricts us from generalizing the results, for example, we did not control the participant sample, and societal and individual differences (e.g., our participants have different cultural backgrounds) may also affect people's attitudes toward robots. However, it enables us to quickly gain initial knowledge of gender differences in this initial exploration.

4.2 Qualitative Results

To explore underlying insights of people's attitudes towards robots, we collected qualitative data with open-ended questions in the survey. We analyzed the data using affinity-diagram-assisted open and axial coding [8], and created affinity diagrams (Figure 4.1) to reveal prominent themes regarding respondent comments about robots en-

(a) The Full Diagram based on 118 Participant's Comments



(b) Subsection of The Diagram

Figure 4.1: Diagrams Resulting from Affinity Diagramming Analysis Technique

tering society. Our analysis revealed that women and men tended to discuss similar broad issues and to 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 present the data with a sex-based cross-analysis of these themes to provide insights into how sex may impact adoption of and interaction with robots.

Quotes are annotated with W(woman) or M(man) with participant number. 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 help them in their personal lives by performing menial, routine tasks, for example, potential benefits of domestic or healthcare robots.

> *"If I develop some sort of condition that requires simple tasks (e.g. reminding me to do something or measuring something simple) then I can imagine a [healthcare] robot could do it." – W20*

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

Although some female participants did mention that they might 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*

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*

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*

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*

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

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*

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*

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*

> *"Entertainment robots are useless, and people already have a lot of ways to entertainment." – W116*

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*

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*

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

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*

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*

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*

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*

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*

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 concerns over a broad range of risks associated with potential robotic malfunction:

> *"Robot does something wrong and breaks things." – W20*

> *"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*

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*

> *"They are not emotional or logical, they are controlled by program or person or a system." – W3*

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*

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 systemfor instance, what comes to my mind is an uncontrolled malfunction." – W29*

while men more often discussed general societal impact:

> *"Malfunctioning [healthcare] robots could lead to improper treatment and could possibly lead to unnecessary deaths." – M87*

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*

> *"I don't really trust any programed device to work in the near future." – M52*

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*

> *"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*

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*

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

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*

> *"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*

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*

> *"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*

overall 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*

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*

> *"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*

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*

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

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 discussed concern 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*

> *"actual human-human contact may be reduced if [entertainment] robots replace partners." – M36*

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*

> *"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*

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*

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

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.

4.2.1 Quantitative Results

In this study, we not only analyzed participant's comments in a comprehensive way, but also explored them from the word level. We performed linguistic analysis of how our female and male respondents discussed robots using the Linguistic Inquiry and Word Count tool [34] that analyzes text for psychological processes and personal concerns (e.g., social, affective, work, leisure, money, etc.). The men (Mean(M)=4.48% of words written) used positive-emotion words more than the women (M=3.30%, U=867.5, z=-1.939, p=.05, r=-.20), and the women (M=0.22%) used family related words more than the men (M=0.07%, U=907.5, z=-2.544, p=.011, r=-.26).

As an exploratory research, we also gathered people's attitudes toward robots with Likert-type scales in the survey. We performed statistical analysis on those quantitative data via 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. A summary of significant results of people's attitudes toward robots and a list of the exact questions are presented in Figure 4.2 for readability.

Men (Mdn=2) were more supportive of domestic robots being developed than women (Mdn=2, U=475, z=-2.84, $p<.01$, r=-.32), while women (Mdn=4) regarded adopting domestic robots as more "risky" than men (Mdn=4, U=501.5, z=-2.67, $p<.01$, r=-.30). Further, men were more positive (Mdn=2) about entertainment robots (women Mdn=3, U=401.5, z=-3.08, $p<.005$, r=-.36), and their potential for impact (men Mdn=2, women Mdn=3, U=499.5, z=-2.08, $p<.05$, r=-.24). Com-

Question	Fem.	Male
should develop domestic robots (1 definitely should, 5 definitely should not)	2(+)**	2(-)
adopting domestic robots is risky to personal life (1 very risky, 5 not at all risky)	4(-)**	4(+)
should develop entertainment robots (1 definitely should, 5 definitely should not)	3***	2
impact of entertainment robots (1 very positive, 5 very negative)	3*	2
adopting entertainment robots is risky to society (1 very risky, 5 not at all risky)	4(+)***	4(-)
adopting entertainment robots is risky to personal life (1 very risky, 5 not at all risky)	4***	5
sex robot is useful (1 very useful, 5 not at all useful)	4*	3
consider buying a sex robot (1 very likely, 5 not at all likely)	5(+)*	5(-)
preferred color tone for a robot (1 cool, 5 warm)	4*	3
preferred color brightness for a robot (1 bright, 5 dark)	3(+)*	3(-)
would feel nervous operating a robot in front of other people (1 strongly agree, 5 strongly disagree)	4(-)**	4(+)
If I depend on robots too much, something bad might happen (1 strongly agree, 5 strongly disagree)	2*	3
I feel that in the future society will be dominated by robots. (1 strongly agree, 5 strongly disagree)	3*	4

Figure 4.2: 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. *$p<.05$, **$p<.01$, ***$p<.005$)

pared with male respondents (Mdn=4), women (Mdn=4) reported that entertainment robots have more social risks (U=389, z=-3.28, $p<.005$, r=-0.38) and personal risks (men, Mdn=5, women, Mdn=4, U=371.5, z=-3.48, $p<.005$, r=-.40).

The only specific robot type with significant effects was sex robots: men (Mdn=3) reported them as being significantly more useful (women, Mdn=4, U=449, z=-2.54, $p<.05$, r=-.30), and men (Mdn=5) were also more willing to acquire a sex robot (women, Mdn=5, U=508, z=-2.05, $p<.05$, r=-.24).

In terms of preferences of robot's physical design, our female participants (Mdn=4) chose warmer colors for educational robots than our male participants (Mdn=2), U=477.00, z=-2.19, $p<.05$, r=-.24, and the women (Mdn=3) tended to choose darker colors for search and rescue robots than the men (Mdn=3, U=544, z=-2.009, $p<.05$, r=-.22). However, these are findings with robotic categories in mind and likely not generalize. For preferences of robot material texture, shape and voice, we applied Chi-Square tests as those results are nominal data. No significant result was found. Supporting data are included in the appendix A.2.

Overall across robot categories, women respondents reported being more nervous to operate a robot in front of others (Mdn=4, men Mdn=4, U=1153.5, z=-2.75, $p<.01$, r=-.25), being more concerned about depending on robots (Mdn=2) than men (Mdn=3, U=1235, z=-2.41, $p<.05$, r=-.22), and about robots becoming out of control (Mdn=3) in the future than men (Mdn=4, U=1305, z=-2.00, $p<.05$, r=-.18). No other significant effects were found.

Although we found some gender differences in people's attitudes toward robot development and robotic impacts on society, there are a lack of results for people's preferences of robotic physical design. One possible explanation is that, when designing the questionnaire, we did not take the influences of particular usage-scenarios on robotic design into consideration. For example, domestic robots could be toys, cleaners, companions that are in personal living environment, and their specific functionalities will heavily impacts their designs, such as their size, texture and body shape. As a result, our over-simplified questionnaire lost some power of observing gender differences. In the future, we should pay more attention to balance varying degrees of specialization and generalization in questionnaire design.

4.3 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. With gender-oriented qualitative analysis, we observed important nuanced differences in terms of how opinions were formed and discussed, differences which can perhaps provide insight into how gender 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 [56, 73]; 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 [71]; 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, if they could get more freedom if robots perform housework. They also expressed a 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 commonly 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, escalation of war, and more commonly used general language in contrast to the female respondent's precise social network references: for example, “soldier” 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 subjects 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 [30]. Further, in comparison to prior work that found that women may focus more on social impact while men focus more on the technology itself [11, 68], 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 the common phenomenon of men having more technology self-efficacy than women, regardless of ability [12]: perhaps men may be more confident and egocentric to provide opinions on broader society while women may simply be more reserved in their opinions, thus limiting them to their own social circles. This self-efficacy disparity may also explain our finding of men in general being more positive toward robots than women, an observation that also mirrors existing work that suggests women perceive more risk than men in making decisions [12, 60].

However, if we abandon the labelling of women as lacking of technical skills 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 (which is part of our functional) needs, including comfort issues such as appropriate social interaction. However, 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 even cold mechanical tools (e.g, a non-social 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.

Overall, the results pointed to the importance of considering sex (and thus, gender) in HRI research, and demonstrated the detailed nuances between men and women rather than construct simplistic gendered categories; in this case, although men and women agreed in general on issues surrounding robots in society, we showed how there were more subtle, important differences.

4.4 Limitations and Future Work

Our broad study design enabled us to explore, but at the cost of limited detail for different types of robots. For example, we covered only a few aspects of domestic robots while this in itself could be a rich area for study. In future, particularly as more robotic products enter the market, we should focus more on a specific area such as domestic or workplace robotic assistants to improve the reliability and generalizability of our research.

In this study, we took the convenience sampling method to recruit voluntary subjects to answer the survey. Although it provided useful data, due to the absence of a probability-based selection procedure, it is difficult to generalize our findings to the general public. Therefore, we should have controls over participant samples in the future, such as rigorously selecting participants evenly through society, to enhance the validity of our gender-related knowledge.

Another 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.

Initial results of this study highlighted nuanced gendered perspectives on robots, such as the personal versus societal perspective between women and men. However, the problem remains of creating concrete tools and guidelines for researchers to leverage to aid them in gender work, and 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 (discussed in Chapter 3). 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.

4.5 Summary

In this chapter, we presented our exploratory on-line study that investigated how men and women view robots. We found that, within our sample, men and women tend to share similar opinions on a broad view of attitudes toward robots in society, such as robot development and design. However, with gendered analysis, our results revealed a range of subtle gender differences that provide insights into how people may perceive and understand robots. One significant finding was the personal versus the societal perspective between women and men. This work illustrates the importance of having gender studies in HRI as gender nuances would be neglected without the gender-oriented exploration and analysis. In addition, bringing our findings together, we proposed two suggestions for future gender studies in HRI:

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. Our data indicated this direction may be more appealing to women, as many women addressed their emotional needs and concerns in human-robot interaction. Gender differences in this direction should get more attention.

Chapter 5

Exploring Differences in Men's and Women's Perceptions of and Interactions with a Robot

The on-line survey results present in the previous chapter provides an initial overview of men and women's general attitudes toward different types of robots in society. In this chapter, we describe a laboratory study that investigates how men and women interact with a robot in a daily interaction scenario. Further, because people attribute gender to robots (described in Chapter 2), as a secondary purpose, this study also explores how the perceived gender of a robot and a person's gender is associated with the perceived personality and capability of the robot.

We start the chapter with background knowledge along with our research questions. Then, we introduce the study design, software implementation and methodology.

After that, the observed results are presented, followed by a discussion of the potential reasons for the results. We end the chapter with some recommendations for gender studies in HRI.

5.1 Background and Research Questions

More and more human-robot interaction will take place in the future, as an increasing number of interactive robots are being used to facilitate everyday life, such as therapeutic seal robot [57], care-giving robot [51], or room service robotic attendant [44], and so on. It is crucial to investigate how people interact with robots socially. One important direction related to our research goal is to learn how gender affects the way people communicate with a robot. As a preliminary exploration, our work deals with how a person's gender affects their interaction with a robot along three dimensions: politeness, engagement and relaxation. The selection of the three categories is based on their importance in interpersonal interaction and the existence of relevant gender effects. Detailed explanations for these three research dimensions are presented below:

Politeness – Politeness is an expression of concern for others' feelings, and it includes both "linguistic politeness" and "behavioral politeness" [39]. It is an important factor in interpersonal interaction [33, 39], for example, politeness in communication has been considered as "a precondition of human cooperation [36]". Further, previous work suggested that women are more polite to others than men in society [39]. Therefore, in this study we explore if the potential gender differences is manifested in HRI: are women more polite to robots than men?

Engagement – In interpersonal interaction, engaging in a communication enables us to gain information about others, to understand others better in a given context, to establish personal identity, etc., and ultimately helps a person interact with others effectively [49]. Further, work in HRI found that people's engagement in interaction could be affected by gender, for example, women reported being more engaged with a male robot, while men reported being more engaged with a female robot (the robot's gender was indicated by the embedded female/male voice) [58]. With the importance of engaging in interaction in mind, we investigate if men and women engage in interaction with a robot differently regardless of the robot's perceived gender.

Relaxation – It is helpful to be relaxed in social interaction, as stress can hinder effective communication by disrupting our ability to think carefully and clearly, and to act properly [52]. Also, the results of our survey suggested that some women present more thoughts and concerns over human-robot interaction, and female participants envision themselves as more nervous when operating a robot than men. Taking the influences of relaxation in communication into consideration, we look into if men are more relaxed while interacting with a robot than women.

Therefore, the leading research question of this work is how men and women interact with a robot regarding politeness, engagement and relaxation. We also look into the effects of a person's gender on perceptions of robots as the secondary purpose. Further, prior work indicated that people assign gender to robots due to the unique physical design of robots (showed in Chapter 2), for example, facial gender cues (e.g., long and curly hairstyle vs. short and straight hairstyle) [26], voices (feminine vs. masculine) [58] or shapes (female-like vs. male-like) [72]. Thus, as a side point, we explores the impacts of a robot's gender on HRI. Below are relevant background and concepts along with research questions.

Gender Cues – As we mentioned above, people attribute gender to robots based on physical features of the robots, such as facial cues or voice cues. In this study, we select a simplistic method, "verbal gender cues," that does not require the modification of the robotic design to assign the robot's gender. The verbal cues are two personal pronouns (she and he), and we verbally address one of the gender cues at the beginning of the study to indicate the gender of the robot. This work tests if our novel method can influence how people perceive the robot's gender.

Gender Stereotypical Personality – The two gender-linked personality dimensions, agency [25] and communion [20, 30], have been widely used in previous gender-related sociological or psychological research [38, 59]. Agency describes people who focus on individual reflection, pursuing social dominance, while communion represents people who focus on relationships with others, ensuring to maintain social bonds [38]. More specifically, agentic traits (such as assertiveness, competitiveness) were associated with personalities of males, while communal traits (such as compassion, empathy) were closely linked to characteristics of females [38, 59]. Based on these dimensions, previous work [26] found that people attribute more communal traits to a female robot and assign more agentic traits to a male robot [26]. However, since this prior study only used the images of virtual robots, it remains unclear how people attribute gender stereotypes to a real robot's perceived personality. Our work aims to learn if people associate gender stereotypes with a real robot's personality according to its perceived gender, and how a person's gender affects their perceptions of the traits of the robot.

Gender Stereotypical Capability – Prior work [26] found that people rate a male robot as being more capable of doing conventional male tasks (e.g., transporting goods, repairing technical equipment, etc.), while a female robot is more capable of doing conventional female tasks (e.g., patient care, childcare, etc.) [26]. However, no previous work explored how people assign gender stereotypical capabilities to a real robot's perceived capability (in contrast to a simulated robot). Therefore, we explore how a real robot's perceived gender is related to its perceived capability, and how men and women perceive a real robot's capability with gender stereotypes in mind.

Overall, the primary focus of this work is to gain knowledge of potential differences between men and women in a situation of interacting with a real robot regarding politeness, engagement and relaxation. Due to the exploratory nature of our research, we also investigate how gender influences people's perceptions of a robot as a secondary purpose: one direction examines how a robot's perceived gender affects how people judge its personality and capability, and the other looks into how men and women associate gender stereotypes with the robot's personality and capability.

5.2 Study Design

In this exploratory study, we created an interaction scenario between participants and a real robot, which provides us with an opportunity to observe how men and women respond to the robot differently. We also collected the subjects' ratings of the robot's perceived personality and capability before and after the interaction to analyze the potential impacts of gender on perceptions of robots. We recruited 41 participants through posters placed around the University of Manitoba: 39 (19 males, 20 females) valid responses and 2 pilots, 74% of them in the age range 18-22, 13 different culture backgrounds (72% Canadians).

The procedure for this experiment was as follows. Participants were given a brief explanation of the experiment purpose and their tasks (talking to the robot and filling out questionnaires) after arriving the lab environment. The study would continue if they signed an informed consent form and received $10 as compensation.

After participants had answered the demographic questions, a researcher introduced the experimental robot with our verbal gender cues to them. Then, the robot stood up to greet participants to show its basic abilities (e.g., speech, flexibility). Participants filled out a questionnaire containing the measures for their perceptions of the robot's personality and capability based on this first impression of the robot (details of the questionnaire presented in below). We counter-balanced the verbal gender cues (she vs. he) and the participant's gender (male vs. female), and only one of the verbal cues were used for any given participant.

In the main interaction session, the researcher addressed the gender cue again by instructing every participant on how to interact with the robot, and then left the participant and the robot in the experiment room. The robot asked questions or answered the participant's questions regarding some daily topics (e.g., study, hobby and work). After the interaction, we collected the robot's perceived personality and capability with another questionnaire, and debriefed the participants before ending the study. The study lasted approximately 30 minutes. Below are detailed explanations of the study setup:

Experiment Environment: The study took place in a room in the University of Manitoba to create a distraction free area. The space was arranged like Figure 5.1. To prevent people from seeing the robot as an unintelligent machine (because the robot does not do anything in the beginning), the participant's back would be towards the robot when they were reading the consent form. After signing the consent form, they would face the robot to continue the study. A video camera was placed in the corner to record the human-robot interaction for later analysis.

Experiment Instrument: We used a commercial humanoid robot developed by Aldebaran Robotics (Figure 5.2). It is a 58 centimeter tall, friendly-looking humanoid robot. It has a built-in speech synthesizer that generates speech. It can also make various gestures with multiple gears covered by its plastic body.

Robot Gender: The gender of the robot was solely determined by the verbal cues, as we used the same robot in our between-participant experiment. To indicate the robot's gender, we introduced the robot's gender-neutral name (Taylor) and its technical abilities with one of our verbal cues (she or he) at the beginning of the study. Here is the introduction of the robot:

> *"Taylor is a human-like robot. She/He can walk. With her/his hand pointing at the robot's hand, she/he can lift things up. She/He can also make various gestures, such as nodding her/his head, waving her/his hand, etc. She/He has advanced artificial intelligence. She/He is not only able to understand you, but can also reply back to you. In the future, she/he may get bigger, stronger, and more intelligent, so that she/he will be capable of doing more tasks."*

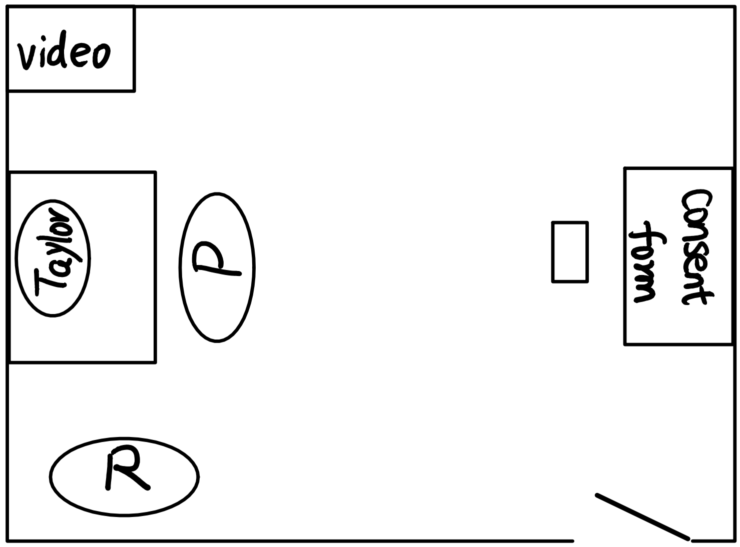


Figure 5.1: Experiment Room Setup (P: participant, R: researcher)

Figure 5.2: The Experimental Interactive Humanoid Robot, Taylor

Beside the robot's technical abilities, we also mentioned possible future changes of our robot in the introduction, such as "she/he may get bigger." It is because we do not want to limit people's perceptions of a robot's capability to our small robot. In other words, we expect participants to imagine and rate the robot's capability beyond its physical design constraints, such as the robot's size.

Interaction Scenario: A 3-4 minute human-robot interaction was included in this study. The robot was designed to speak with each participant about three daily topics, which include asking the participant's hobbies or their school/work related questions. However, due to the limited social interactive ability of our robot, we let a researcher control the robot remotely via a robotic control interface, to generate relatively natural "interpersonal" interaction between participants and the robot. The implementation of the robotic control interface is described in the following section.

Here is an example of the interaction scenario: the conversation usually started with the robot asking about the participant's prior experience with interacting with robots, then the robot would ask a few questions regarding the participant's study and (or) work, followed by questions related to their hobbies. To mitigate confound variables in this real interaction, we predefined questions under each topic and short answers for anticipated questions from the participant. For unexpected questions, the wizard-of-oz method enabled our robot to "answer" them with the help from the unseen researcher. Further, if our participants got off-topic, the robot would ask certain predefined questions to bring the topic back, such as "can we talk about something else?" In this study, we tried to cover all the topics, which means each topic may last around 1 minute. However, the freeform interaction and personal variance still introduced some unknown impacts to our findings.

Overall, we believe that this interaction helps us to elicit people's real immediate reactions and responses to a robot, which improves the validity of the findings compared with previous gender-related study in HRI, although it is a short interaction and the robot was being controlled by our researcher,

Questionnaires: We designed three questionnaires for this study. The pre-test questionnaire was used to collect people's demographic information. It includes questions regarding gender, technical knowledge, mother tongue and culture background.

To get perceptions of the robot's personality and capability, we made a questionnaire with relevant word categories provided by prior work [26], which contains 24 adjectives to describe personal traits (12 communal and 12 agentic) and 12 gender stereotypical tasks (6 conventionally female tasks and 6 conventionally male tasks). Participants answered the perception-related questions using seven-level likert scales from "strongly disagree" to "strongly agree." We averaged each participant's ratings of the words related to stereotypical masculine or feminine personality or capability, and used the mean to reflect their perceptions of the robot's traits or abilities.

In our post-test questionnaire, besides the perception-related questions mentioned above, we included a few more questions. We asked people to rate the robot's perceived gender on a seven-level scale from "rather female" to "rather male." This question was used to determine if the verbal cue made the person see the robot as female or male. We completed this questionnaire with an open-ended question where participants were able to freely write comments about the robot. All questionnaires are attached in Appendix B.1.

5.3 Implementation

To remotely manipulate the robot in the study, we developed a robot controller interface (Figure 5.3) using the Python programming language. The interface offers labeled buttons to assist our researcher choosing desired questions or short answers in the interaction (top right), which were predefined along with robotic body gestures to mitigate confounding variables. One empty text box at the bottom of the interface enables the robot to give responses to participants' unexpected questions, as the researcher can type in reasonable answers and press the "say" button to let the robot speak out the answer, thus maintaining the natural interactive process. The left part of the interface is mainly comprised of robot vision (top) and the robotic action controller (bottom). The vision of the robot provides visual feedback to the researcher in the interaction, and the action controller allows the researcher to edit robotic behaviors in case mistakes or emergencies happen.

5.4 Analysis Methods

In this research, we conducted a 2 by 2 between-participant study with independent variables the participant's gender (male vs. female) and the robot's gender (she vs. he). Therefore, for the quantitative data acquired from the questionnaires, we employed the two-way ANOVA, which is commonly used to examine the influences of two

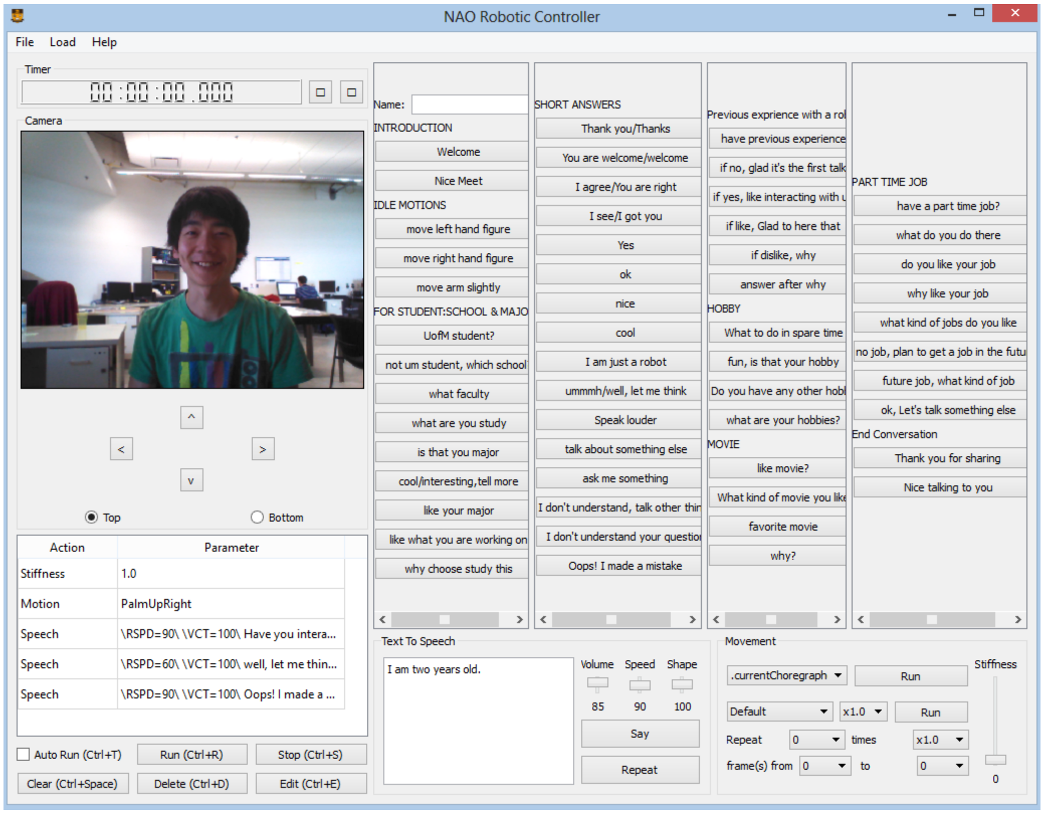


Figure 5.3: Robot Controller Interface

difference independent variables as well as their possible interaction.

To analyze how men and women interact with a robot differently regarding their politeness, engagement and relaxation, two researchers coded the interaction videos with commercial software (Nvivo) based on our coding guidelines, and then we applied the two-way ANOVA on the quantified data. As we observed both positive and negative sides of the three selected directions, there were six dependent variables (or main codes) in the exploration of gender differences in the interaction (illustrated in Figure 5.4). In the coding guidelines, we provided explanations of dependent variables and examples of relevant instances or behaviors. Further, each dependent variable

Dependent Variable	Code	Brief Description
Positive Politeness	PP	behave in a respectful or considerable way
Negative Politeness	NP	act impolitely or say impolite things
Positive Engagement	PE	actively involved in or show interests in
Negative Engagement	NE	simply not engaged or interested in
Positive Relaxation	PR	being calm or less worried
Negative Relaxation	NR	being nervous or tense

Figure 5.4: All Dependant Variables Observed In the Interaction

contains four sub-codes with instances to help researchers understand what we were looking for, and further help them code relevant behaviors in similar ways.

The main reason for having four sub-codes is that many factors impact social interactions [52]. For example, people judge if a person is polite based on his/her wording and manners [39]. Therefore, we have codes for addressing verbal politeness, such as saying "sorry" or "please" to the robot. Codes for highlighting polite interactive behaviors are also included, such as "remember the robot's name," "give positive feedback about the robot's performance," etc. However, for final analysis, the sub-codes were aggregated into their primary category only (e.g., positive politeness). Coding guidelines for politeness and rudeness are showed in Figure 5.5. The complete coding guidelines for our three main categories are in Appendix B.2.

In the coding process, whenever we observed relevant behaviors regarding participant's politeness, relaxation and engagement, we would add notes to the related interaction interval (around 5 seconds). If a continuous behavior last more than 15s, we coded it again. For example, we considered smiling naturally to the robot in the conversation as positive relaxation, but some people kept smiling. To avoid overly

Positive (polite): standard: participants give polite responses to the robot's questions/requests during the conversation.	**Negative (rude):** standard: participants ignore the robot's questions/requests during the conversation
examples for short instances: **Code PP**	examples for short instances: **Code NP**
PP1: <u>give polite responses to robot politeness</u>: when robot says "nice talking to you/nice to meet you," "thank you/thanks," "...please...," participants give responses politely. **PP2:** <u>polite to robot's requirements</u>: e.g., "can we please talk about something else," "could you speak a bit louder," participants agree. **PP3**: <u>participants are being polite actively:</u> asking the robot's feeling actively, such as "how are you today," "Hi," etc., before the robot starts talking; remember robot's name; say "thanks/ sorry/please" to the robot actively. **<u>PP*</u>**: some cases may be not covered by the upper instances, but it's clear that the participant is being polite. Eg., people give positive feedback about the robot's performance.	**NP1:** <u>ignore robot's politeness:</u> robot says "thank you," "nice talking with you," etc., and participants don't give any response or give an unusually short response; participants changed topics for personal needs **NP2:** <u>ignore what the robot questions/requests</u> **NP3:** <u>participants are distracted</u>, e.g., look around, play with their cellphone. Note, if the robot/people not talking with each other, it is okay to look around. **<u>NP*</u>:** some case not being covered by the upper instances, but it's clear that the participant is being rude. Eg., looking around while talking with robot (extreme)

Figure 5.5: Coding Guidelines for People's Politeness or Rudeness

coding similar common behaviors, we decided to take 15-20 seconds as a boundary based on the amount of codes we added in the coding process (not too many or too few). For illustrative purpose, we present a scene in the experiment (Figure 5.6) with the descriptions of how we coded and interpreted the participant's interactive behaviors.

We coded the participant as being engaged in the interaction because she leaned forward to talk to the robot, and also noted that she was relax as she looked at the robot with a smiling face. We coded the participant being polite in this five-second interaction due to her polite responses to the robot in the video as well.

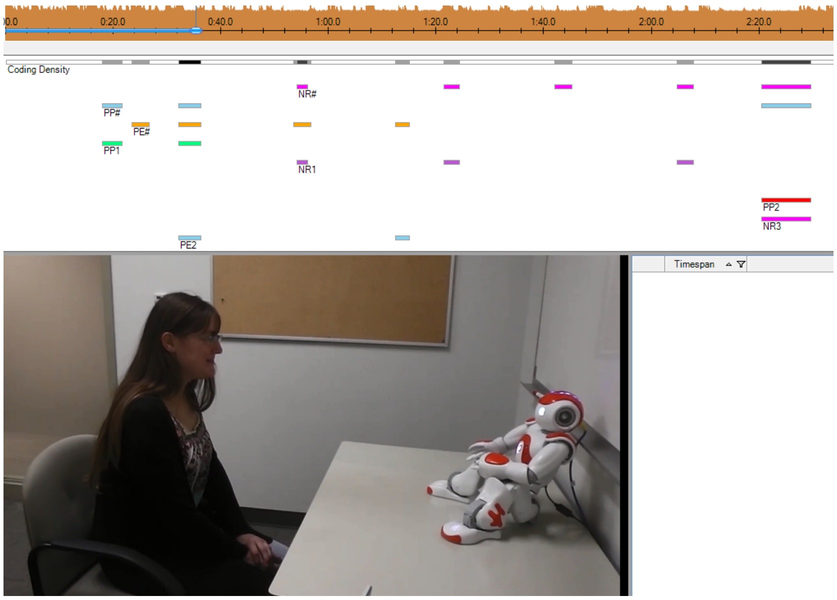


Figure 5.6: One Scene Shows The Participant's Relaxation and Engagement (image used with permission)

5.5 Results

Overall, the data suggested that our male and female participants tend to perceive and interact with our robot similarly. With the gender-oriented analysis, a few subtle gender differences were revealed. We present all significant results below.

5.5.1 Gender Impacts on People's Perceptions of The Robot

In the investigation of the impacts of a person's gender, there was a significant main effect of a person's gender on people's ratings of the robot's capability of doing conventional female tasks before the interaction, $F(1,35)=6.748$, $p<.05$. Specifically, our male participants (Mean(M)=4.84, Standard Error(SE)=.198) on average reported that the robot suits traditional female tasks higher than our female participants did

(M=4.10, SE=.204) before the interaction. However, the same effect was not found after the participant interacted with the robot, as there was a non-significant effect of a person's gender on the robot's perceived capability of doing stereotypical female tasks after the interaction, $F(1,35)=3.722$, $p=.62$. No significant interaction found between the robot's gender and the participant's gender on perceptions of the robot's abilities of traditional female tasks was found, no matter it was before ($F(1,35)=2.628$, $p=.114$) or after the human-robot interaction ($F(1,35)=.733$, $p=.398$).

Our data also suggested that participants were influenced by verbal cues regarding the robot's gender. More specifically, the robot introduced with "he" was rated as more masculine (M=4.76, SE=.28), whereas the robot introduced with "she" was perceived as more feminine (M=2.90, SE=.29), $F(1,35)=20.830$, $p<.001$. However, we did not find that the person's gender significantly affects the robot's perceived gender, $F(1,35)=1.867$, $p=.181$. No interaction between the robot's gender and the participant's gender on the perceptions of the robotic gender, $F(1,35)=.146$, $p=.704$.

As to the influences of the robot's gender implied by previous work, we failed to find any significant effects on perceptions of the gender-related stereotypical personality and capability of the robot. Before the interaction, there were non-significant effects of a robot's gender regarding the robot's perceived female traits ($F(1,35)=.17$, $p=.683$), perceived male traits ($F(1,35)=.458$, $p=.491$), perceived capability of doing stereotypical female tasks ($F(1,35)=.153$, $p=.698$), and perceived capability of doing stereotypical male tasks ($F(1,35)=.036$, $p=.85$). There were still no significant effects of a robot's gender after the interaction regarding those perceived personalities and capabilities: female personality ($F(1,35)=1.118$, $p=.298$); male personality (F(1,35)=.703, p=.407); female tasks (F(1,35)=.52, p=.476); and male tasks (F(1,35)=.044, p=.836).

5.5.2 Gender Effects on The Interaction with The Robot

After the two researchers coded the video data, we examined the reliability of the quantified data obtained from the coding process. We calculated inter-coder reliability using Krippendroffs Alpha (Kalpha) [64] with the coding data from the 12 overlapped videos. The kalpha values for all six dependent variables were ≥ 0.79, which indicated that our coding results were reliable with the final coding guidelines.

With the number of codes under each dependent variables, we statistically analyzed people's politeness, relaxation and engagement with the two-way ANOVA. The only significant result was that our male participants were more rude (NP) to the robot in the conversation (M=1.05, SE=.308) than our female participants (M=.15, SE=.317), F(1,35)=4.142, p<.05. No significant main effect of the robot's gender on people's impoliteness, F(1,35)=.205, p=.654. In addition, there was a non-significant interaction between the robot's gender and the participant's gender regarding people's rudeness to the robot, F(1,35)=1.278, p=.266.

To analyze our data from more perspectives, we not only observed p-values, but also looked into the effect size (Cohen's d) and the observed power for all dependent variables regarding the robot's gender or the participant's gender (Figure 5.7). As an effect size of 0.2 or less could be considered as a "small" effect [16], the small effect sizes of most of our dependent variables suggested that, even if we had a larger sample size, we would get similar results: only a few gender effects. The small observed power

dependent variables		independent variables			
		robot gender		participant gender	
perceptions		**effectsize**	**observed power**	**effectsize**	**observed power**
Before Interaction	Female Tasks	0.062	0.054	0.396*	0.226*
	Male Tasks	0.026	0.051	0.197	0.165
	Agentic Traits	0.110	0.063	0.172	0.136
	Communal Traits	0.071	0.055	0.164	0.128
After Interaction	Female Tasks	0.118	0.065	0.311	0.157
	Male Tasks	0.037	0.052	0.054	0.058
	Agentic Traits	0.122	0.066	0.161	0.126
	Communal Traits	0.174	0.083	0.022	0.051
robot-gender		0.597*	0.442*	0.163	0.128
interaction					
Negative Enagement		0.160	0.078	0.107	0.062
Negative Politeness		0.084	0.058	0.317*	0.161*
Negative Relaxation		0.125	0.067	0.078	0.057
Positive Engagement		0.083	0.057	0.100	0.061
Positive Politeness		0.007	0.050	0.128	0.068
Positive Relaxation		0.101	0.061	0.019	0.050

Figure 5.7: Effect Size (Cohen's d) and Observed Power for All Dependent Variables based on Robot's Gender or Participant's Gender (* indicates the significant effect)

of most dependent variables indicated that we did not have enough statistical power to say that gender affects people's perceptions of and interaction with a robot in this study; however, we also can not claim that there is no gender difference. In short, there might be only subtle gender impacts even if we had more participants.

With the individual variances in mind, we calculated mean values and standard deviation for all dependent variables (Figure 5.8) to get an overall sense of variations in how people perceive and interact with a robot. The relatively low standard deviations in the perception-related variables indicated that our participants rate the robot's personal traits and abilities in a similar manner. While the high standard deviations of people's attitudes towards the robot in the interaction implied that our participants

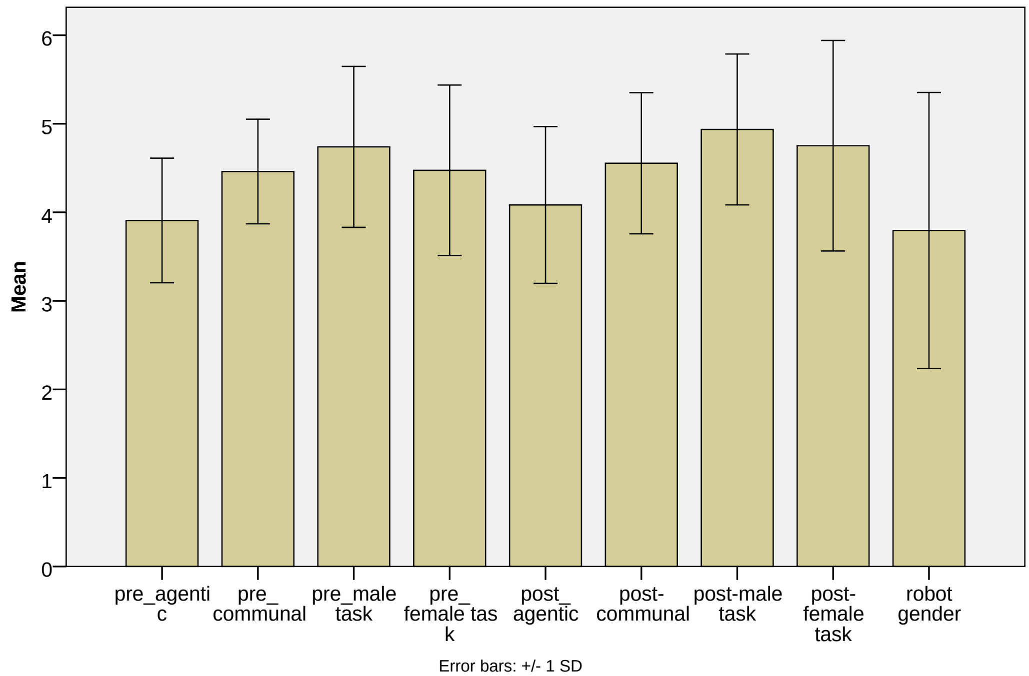
perceptions		Mean	SD
Before Interaction	Female Tasks	4.47	0.96
	Male Tasks	4.74	0.91
	Agentic Traits	3.91	0.70
	Communal Traits	4.46	0.59
After Interaction	Female Tasks	4.75	1.19
	Male Tasks	4.94	0.85
	Agentic Traits	4.08	0.89
	Communal Traits	4.55	0.80
robot-gender		3.79	1.56
interaction		**Mean**	**SD**
Negative Enagement		1.18	1.17
Negative Politeness		0.62	1.43
Negative Relaxation		2.46	2.82
Positive Engagement		7.74	3.06
Positive Politeness		4.59	1.53
Positive Relaxation		7.87	3.83

Figure 5.8: Mean Values and Standard Deviations (SD) for All Dependent Variables

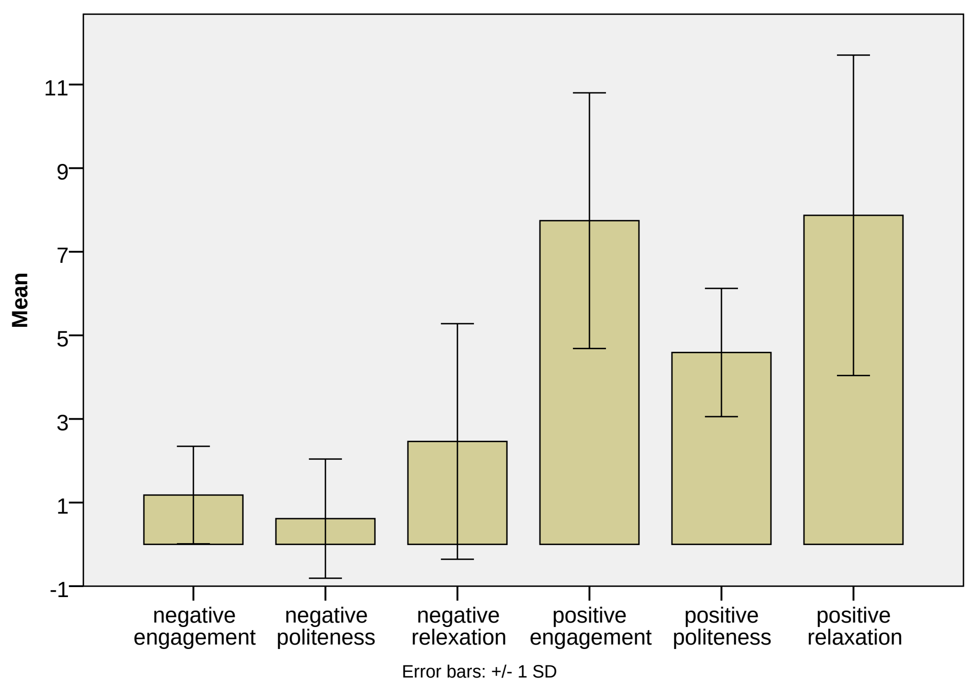
are quite different from each other when interacting with a robot regarding their politeness, relaxation and engagement. Therefore, the gender differences might be mitigated or washed out by individual variances in the human-robot interaction. The related bar charts show the dispersion of people's perceptions and the variation of their attitudes toward our robot in the interaction (Figure 5.9).

5.6 Discussion

Overall, our analysis revealed that our male and female subjects both treated the robot politely, and relaxed and engaged in the conversation in general, except our male subjects were slightly more rude to the robot. In other words, our data failed to find the expected gender differences in the interaction based on the stereotypical assumptions: women are more polite to the robot than men, and men are more re-



(a) Mean Values and Standard Deviations of People's Rating of The Robot's Perceived Personality, Capability Before and After Interaction, and Perceived Gender



(b) Mean Values and Standard Deviations of The Numbers of Observed Behaviors Regarding The Three Selected Categories in the Interaction

Figure 5.9: Mean Values and Standard Deviations for All Dependent Variables

laxed and engaged in the communication than women. Therefore, robotic researchers should be aware of gender-related stereotypical assumptions in social interaction, and understand those stereotyped gender differences may not salient in the field of HRI.

With regard to the effects of a person's gender on perceptions of robots, we found that, within our sample, men and women tend to perceive the robot's traits and abilities similarly, such as both men and women rate our small humanoid robot as being capable of traditionally female tasks. However, with the gender-based analysis, some gender nuances were uncovered, more specifically, our male participants rated the robot as suited for conventional female tasks more than the females did before the interaction. Our findings support the importance of having inclusive robotic design, as men and women not only have innate differences, but also share many similarities in their attitudes toward and interaction with robots.

As to the influences of the robot's perceived gender, although the verbal cues indicated a robot's gender successfully, we did not find as many gender differences as prior work [26], such as people perceive a robot's personality and capability based on its gender. This kind of disagreement raises the need of re-defining and updating the gender-related knowledge in HRI.

5.6.1 Limitations and Future Work

Our laboratory study enabled us to observe people's immediate reactions to the robot by including a real human-robot interaction. However, it increased the complexity of the study and raised the chance of having confounding variables (in comparison to previous work that used only photos of robots [26]), which disrupt us from pursuing gender differences in men and women. In this section, we provided several potential reasons for not finding expected gender differences in this work.

One reason might be the physical design of our experimental robot. In this study, we used a small, friendly-looking humanoid robot. Its appearance may limit people's imaginations of its capabilities, as some participants told the researcher after the experiment that it was hard for them to image the small robot operating other machines or repairing equipments (typical male tasks). This might partially explain why both men and women rated our experimental robot as suited for typical feminine tasks, which requires less physical power. In other words, the impacts of the robot physical design might be stronger than participant's gender influences on people's perceptions of robots. One important future work is the exploration of how different physical designs of robots influence people's perceptions of their capability, such as the humanoid robots with different height, to improve the understanding of effects of robotic designs on perceptions of robots. Further, the impacts of gender-neutral robotic design (no facial gender cue, no feminine or masculine voice) on perceptions of robots are unclear, it is also important to investigate the impacts of gender-neutral design on people's perceptions of a robot in the future.

The limited interactive capability of the robot could be another reason, as our robot was not able to convey human-like personal traits accurately. For example, its slow responses to participants' questions greatly impacts its ability to show some masculine traits, such as "determined," or "confidence," etc. This limitation might reduce the possibility of our participant associating gender stereotypical personalities (for human beings) with the robot. That is to say, the current robotic technology restricts the robot from performing as a human, which further affects how people attribute gender-oriented human personality and capability to a robot. In the future, we can reproduce the experiment with a more intelligent robot, that performs like a human-being autonomously, to investigate gender impacts.

Although our results indicated that people perceived the robot's gender along the verbal cues (she vs. he), it remains unclear that how verbal indicators impact perceptions of robots in the long term. Therefore, the unknown long-term effects of verbal gender cues could be another confounding variable. In previous studies, people modified robotic physical design to indicate their gender, such as gendered hairstyles, masculine versus feminine voices or shapes [26, 58, 72]. These gender cues are able to continuously remind people the robot's gender. However, we only used verbal cues twice in our study (the introduction and the interaction phases). Thus, a promising future work is to explore how physically designed-in gender cues and our verbal cues affect perceptions of robots differently.

Further, our freeform interaction setup may have introduced some confounding factor into the data. To mitigate the influences of this design, we tried to cover all the selected topics by using predefined questions and answers in the interaction. However, due to interpersonal differences, the inconsistency of the topics might be problematic. For example, some people only talked about two topics with the robot as they tended to give informative and complete answers, some covered all the selected topics, while others asked the robot questions regarding their personal interests instead of continuing the selected topics. In the future, we could introduce the scope of the topics before the real interaction to mitigate some potential confounding variables.

The last factor we would like to mention is our participant sample. Our results suggested that there might be small gender differences even if we recruited more people; however, we need to be aware of the composition of our participant sample. The participants all volunteered to participate in this experiment, meaning that anyone uninterested or scared of robots, may have simply passed up on the study. This type of participants may mislead our findings on gender differences in the interaction, especially regarding relaxation and engagement. This concern is supported by high standard deviations of the interaction-related variables in our work (Figure 5.8). Those values indicate that the interpersonal variance were quite big, which might mitigate gender differences in the human-robot interaction.

5.7 Summary

In this chapter, we described a laboratory study that we conducted for exploring gender differences in how men and women perceive and interact with a real robot. This study involved a real human-robot interaction, where the robot was controlled by our robot controller interface. The results show that, within our sample, men and women tend to perceive the robot's personality and capability similarly, and they also interact with the robot in similar manners regarding politeness, relaxation, and engagement. With the gender-oriented analysis, a few gender differences were found. For example, our male participants on average were more rude to the robot than the females in the interaction. However, we did not find possible links between the robot's perceived gender and perceptions of the robot's personality and capability, which is different from prior findings. Based on our results, we can see that ongoing gender-oriented explorations are needed to update and refine the gender-related knowledge in HRI. In addition, we propose two suggestions for gender studies in HRI:

Verbal Gender Cues – Our participants attributed gender to the real robot based on the verbal cues (she or he) used in the experiment introduction and interaction phases. This new way enables robotic researchers to assign robot's gender without modifying physical design of robots, which could simplify the future gender studies in HRI. However, it may need further evaluation.

Gender Stereotypes In Society – We found that people may apply stereotypical knowledge from human society to perceive and interact with a robot. In this study, both men and women rated our robot as suited for stereotypical female tasks. They also treated the robot politely, and felt relaxed and engaged in the interaction just like it is a social entity. HRI designers should be aware of gender-related stereotypical assumptions, and gender differences in this direction should be carefully examined as it will further develop the understanding of robotic designers on men and women's expectations of robots' interactive performance.

Chapter 6

Conclusion

In this thesis, we took a multifaceted approach to explore what role a person's gender plays in their perceptions of and interaction with robots. We developed a theoretical grounding for gender studies in HRI by reviewing the general field of gender studies and surveying the current gender representation in research published in HRI. The foundations highlighted the importance of having gender sensitivity in robotic research, proposed a promising direction (inclusive gender design) for gender studies in HRI, and revealed the current status of gender-related explorations in the field.

We also got an initial overview of men and women's attitudes toward robots using the exploratory on-line survey. We found that, in our sample, men and women tend to share similar opinions on a broad view of attitudes toward robots in society. With gender-based quantitative and qualitative analysis, we were able to find a range of subtle gender differences and provide insight into how men and women may perceive and understand robots. One important finding was the personal versus the societal perspective in women and men's discussion of the impacts of robots. Further, this study illustrated the importance of having gender-oriented research, as some subtle, yet fundamental, gender differences might be ignored without them.

In the exploration of how men and women interact with a real robot, we conducted a laboratory experiment and observed people's real-time reactions to the robot in the interaction. In this study, we failed to find clear and obvious gender differences in HRI with regard to stereotypical assumptions. For example, we did not find that women are more polite to robots than men although women are perceived as more polite to others than men in society. Therefore, robotic researchers should be aware of stereotypical assumptions about men and women interacting with robots, and understand that they may not be as salient as believed in HRI.

We also analyzed the impacts of the participant's gender and the robot's gender on people's perceptions of robots based on self-reports from participants as the secondary purpose of the laboratory study. The results revealed that there was no obvious difference in terms of how our female and male participants attribute gender stereotypical personality and capability to the robot. Further, although our novel approach (i.e., using "he" or "she" verbally to introduce the robot) successfully indicated the robot's gender, we failed to find the same effect of the robot's gender implied by previous research, such as the perceived gender of a robot affects how people attribute gender stereotypes to the robot's traits and abilities.

Overall, in this research, we provided robotic researchers with the initial gender-studies foundations, and conducted two empirical studies to reveal gender differences and the possible impacts of gender in people's attitudes toward and interaction with robots. The results improve the knowledge about the impacts of gender in HRI, indicate the importance of developing gender sensitivity in the field, and promote the need for more gender studies to update and refine gender-targeted knowledge in HRI. We conclude this thesis by discussing several directions for future research and presenting the research contributions.

6.1 Limitations and Future Work

As an initial exploration, this thesis explores and frames the impacts of gender on HRI from various perspectives. However, the gender-technology relationship is not simply a static result of study, but is rather an ongoing complex process. Therefore, HRI-specific gender studies will also require a continuous concerted effort spanning research expertise and cultures. Our findings raise a rich breadth of future work for this ongoing process, as briefly discussed below:

One possible future direction is the exploration of targeted robotic types. In our on-line survey, we explored various robotic types at the cost of limited detail for different types of robots. Further, the survey results also indicated that men and women may be interested in certain robotic categories (e.g., healthcare robots for women vs. educational robots for men). An important future work is looking into the robotic categories that are more appealing to men or women, and investigates people's attitudes toward those targeted robotic types to provide insights on men or women's preferences and concerns about them.

The results of the on-line survey suggested that women may put more thought into robotic influences beyond utilitarian gain, possibly more than men. For example, many women addressed their personal emotional needs and concerns in human-robot interaction while much fewer men commented on that. A promising direction would be to learn the differences in men and women's attitudes toward emotional gains obtained from having or interacting with robots.

Another possible future work is to examine the impacts of gender while considering the influences of other demographic variables. For instance, as previous work showed that different cultures have influences on HRI [41], one valuable future work is to explore how culture and gender influence perceptions of and interaction with a robot.

In the in-lab study, we not only probed the potential impacts of a person's gender, but also touched on the possible effects of the robot's perceived gender and the interaction of these two independent variables. Although our study did not reveal the effects between person's gender and the robot's gender, there was evidence of the cross-gender impact implied by prior work, such as people are more engaged in conversations when talking with a robot of the opposite-sex [58]. Moving forward the field, it will be important to discover more cross-gender effects and how this could be leveraged in robotic design and HRI, such as will men be more patient to female robots in the human-robot interaction.

To gain initial knowledge of how a robot's gender may impact human-robot interaction, we limited our preliminary in-lab exploration by using a simply dichotomous gender division, male versus female. However, not everyone perceives robots as social entities [54], which means that some people may perceive robots as gender-neutral objects. Therefore, it is crucial to extend this direction by investigating how a gender-neutral robot affects the human-robot interaction.

Finally, while our work provided useful sensitizing information for robotic researchers using sex as a sampling method, such as the societal versus personal perspectives between men and women, we understand that gender does not simply fit into biological sex. Thus, one important future direction is to consider including a more diverse representation of gender, and how the fine-grained categories of gender relate to people's attitudes toward and interaction with robots.

6.2 Contributions

Bringing our exploration approaches and results together, our work has contributed to the field of HRI by presenting:

- Gender-Studies Foundations – We presented arguments for why gender is important and can not be ignored in HRI, why inclusive gender design should take place rather than harmful stereotype-entrenching design, as well as provided the current status of gender studies in HRI.
- Suggestions for Gender Studies – We presented a set of suggestions to provide a gender-sensitive voice to both women and men's concerns and opinions, and to unpack many relevant HRI issues from a gender-related perspective.
- Exploratory Approaches – We conducted an on-line survey and a laboratory study and highlighted the possible disadvantages and advantages of these ap-

proaches. It provides lessons and examples of how to apply these methods to future gender-related research in HRI.

- Gender Differences – We found some subtle differences in HRI, such as personal versus societal perspective between women and men, which put robotic practitioners in an improved position to predict, accommodate for, and even leverage gender effects in robot designs.

Overall, this thesis contributes knowledge to improve the profile and visibility of gender studies in HRI, and serves as a source and foundations from which other HRI gender studies can build from. We hope that this direction continues to grow and that ultimately researchers aim for inclusive gender design for all robotic users.

Appendix A

Supporting Data for The On-line Survey

In this appendix, we present our full-version questionnaire used in the on-line study, as well as our quantitative analysis results (Chapter 4).

A.1 The Questionnaire for Our On-line Survey

The below questionnaire is the one we used in our online survey study.

Part 1: Personal Profile

1) **What is your biological sex?**
   A. Woman
   B. Man
   C. Intersex

2) **What is your age?**
   ______

3) **What is the highest level of education you have received?**
   A. High School or less
   B. College diploma
   C. Professional Trade certificate
   D. Undergraduate degree
   E. Graduate degree
   F. Other, please specify_______

4) **Do you live with…?**
   Check any that apply
   ☐ A parent or parents
   ☐ A significant other or partner
   ☐ Your child or children

5) **Which country do you primarily live in?**
   ______

6) **Do you have prior experience with a robot, such as interacting with one at a school or museum, owning one, or building one?**
   A. Yes, I do
   B. No, I do not

If yes, please briefly explain which kind of experience you have had.

Part 2: Perception on General Robot

Please fill out the following form:

Here are 14 statements about robots. You will probably find that you agree with some of the statements and disagree with others, to varying extents. Please indicate your reaction to each of the statements with a check mark symbol "√". There is no right or wrong answer, just give your first impression.		**strongly disagree**	**disagree**	**neutral**	**agree**	**strongly agree**
1	I would feel uneasy if robots really had emotions.					
2	Something bad might happen if robots developed into living beings.					
3	I would feel relaxed talking with robots.					
4	I would feel uneasy if I was given a job where I had to use robots.					
5	If robots had emotions I would be able to make friends with them					
6	I feel comforted being with robots that have emotions.					
7	The word "robot" means nothing to me.					
8	I would feel nervous operating a robot in front of other people.					
9	I would hate the idea that robots or artificial intelligences were making judgements about things.					
10	I would feel very nervous just standing in front of a robot.					
11	I feel that if I depend on robots too much, something bad might happen.					
12	I would feel paranoid talking to a robot.					
13	I am concerned that robots would be a bad influence on children.					
14	I feel that in the future society will be dominated by robots.					

Part 3: Perception on Various Robot's Roles and Appearance

Please read the below text and questions carefully and rate your opinion of each.

Entertainment Robots:

Entertainment robots are designed to please their users. For example, 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.

General Opinions:

1) **In general, do you think that governments, research organizations, or companies should spend time and money on developing Entertainment Robots?**

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

2) **Do you think that Entertainment Robots will become more common in people's daily lives in the near future?**

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

3) **In what way do you think that Entertainment Robots could impact your life**?

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Entertainment Robots may impact your life:

4) **Do you think that, in general, there are risks involved with adopting Entertainment Robots in society?**

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

5) **Do you personally feel that there would be risks involved with deploying Entertainment Robots yourself?**

very	**risky**	**moderately**	**slightly**	**not at all**

risky		**risky**	**risky**	**risky**
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of entertainment robots. Please carefully consider and rate your opinions.

1) Dancing/ Singing Robot: These robots can sing songs and dance, or do public performances to entertain audiences.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

2) Companion/ Pet/ Toy Robot: These robots are designed to be interactive pets, companions, and friends, perhaps playing games, keeping people company and helping with loneliness.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

3) Sex Robot: These robots are designed to perform sexual acts with people.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

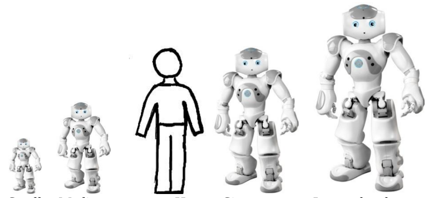
very likely	likely	moderately likely	slightly likely	not at all lightly

☐	☐	☐	☐	☐

Appearance:

1) Size

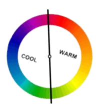
In general, which size would you prefer for an Entertainment Robot?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour

Colours can be categorized as either "cool" or "warm," as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for an Entertainment Robot?

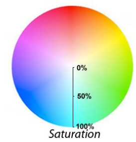
Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.

Which level of brightness would you prefer for an Entertainment Robot?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for an Entertainment Robot?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures

Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for an Entertainment Robot?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

4) Shape

Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for an Entertainment Robot?

Animal-Like Robot	Human-Like Robot	Machine-Like Robot	Other
☐	☐	☐	

5) Voice

Which voice would you prefer for an Entertainment Robot?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Educational Robots:

Educational robots are designed to help with student education, for example, as robot tutors at home, as in-class robotic teaching assistants, or as full-fledged teachers to replace a person.

General Opinions:

1) **In general, do you think that governments, research organizations, or companies should spend time and money on developing Educational Robots?**

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

2) **Do you think that Educational Robots will become more common in people's daily lives in the near future?**

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

3) **In what way do you think that Educational Robots could impact your life?**

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Educational Robots may impact your life:

4) **Do you think that, in general, there are risks involved with adopting Educational Robots in society?**

very risky	risky	moderately risky	slightly risky	not at all risky
☐	☐	☐	☐	☐

5) **Do you personally feel that there would be risks involved with deploying Educational Robots yourself?**

very risky	risky	moderately risky	slightly risky	not at all risky
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of educational robots. Please carefully consider and rate your opinions

1) At-Home Robotic Tutor: These robots could help parents with tutoring their children at home, ranging from pre-school education all the way to high school help. Such robots could help with school work and also cover additional knowledge not covered in the classroom.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly

☐	☐	☐	☐	☐

2) In-Class Robotic Teaching Assistant: These robots could aid teachers in their daily work by answering student questions, or by providing advanced teaching tools (such as real-time graphics and simulation) to teachers during lectures.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

3) Robotic Teachers to Replace People: These interactive robots could teach entire classrooms of students, using a vast knowledge base and real-time internet connectivity. The robots will be particularly useful where there are shortages of human teachers, such as in remote areas and developing countries.

Do you think this function is useful?

5 (very useful)	4	3	2	1(not useful)
☐	☐	☐	☐	☐

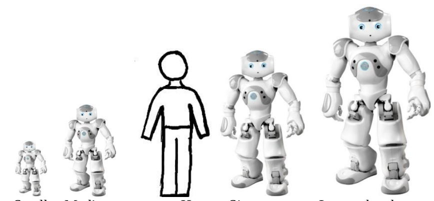
Do you think schools should consider buying this kind of robot?

5 (should)	4	3(neutral)	2	1(should not)
☐	☐	☐	☐	☐

Appearance:

1) Size

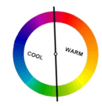
In general, which size would you prefer for an <u>Educational Robot</u>?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour

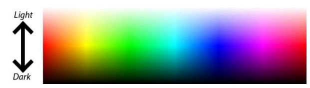
Colours can be categorized as either “cool” or “warm,” as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for an <u>Educational Robot?</u>

Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

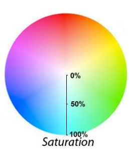
The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.



Which level of brightness would you prefer for an <u>Educational Robot</u>?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for an <u>Educational Robot</u>?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures

Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for an <u>Educational Robot</u>?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

If other, specify:

4) Shape

Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for an <u>Educational Robot</u>?

Animal-Like Robot	Human-Like Robot	Machine-Like Robot	Other
☐	☐	☐	

5) Voice

Which voice would you prefer for an <u>Educational Robot</u>?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Interactive Healthcare Robot:

Interactive healthcare robots are designed to help people in ways that has traditionally been done by another person. For example, a nurse robot may take a patient’s vital signals, may do basic diagnostic testing, may aid with rehabilitation exercises or with taking complex medicine regimes, or may be an in-home care assistant helping people with mobility issues, etc.

General Opinions:

1) **In general, do you think that governments, research organizations, or companies should spend time and money on developing Healthcare Robots?**

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

2) **Do you think that Healthcare Robots will become more common in people’s daily lives in the near future?**

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

3) **In what way do you think that Healthcare Robots could impact your life**?

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Healthcare Robots may impact your life:

4) **Do you think that, in general, there are risks involved with adopting Healthcare Robots in society?**

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

5) **Do you personally feel that there would be risks involved with deploying Healthcare Robots yourself?**

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of interactive healthcare robots. Please carefully consider and rate your opinions

1) In-Hospital Nurse Robots: These robots could do initial diagnostic patient testing, assist with delivering and giving medicine, food, and so on. Such robots could improve accuracy and consistency of these operations.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

2) Mobility-assistant Robots: These robots could help people with mobility issues, such as those with injuries, disabilities, or illnesses. These robots could be in-home permanent assistants, helping with daily activities such as bathing, or helping to move around for exams and exercises.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

3) At-Home Medical Assistant: the robots can help with medicine reminders, monitor people and call for help if needed, serve as companions or play simple mental-exercise therapy games for those suffering from mild dementia.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

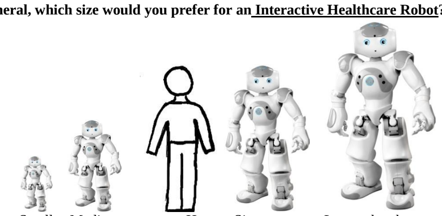
Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

Appearance:

1) Size

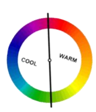
In general, which size would you prefer for an <u>Interactive Healthcare Robot</u>?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour

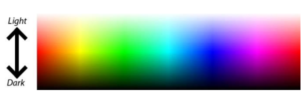
Colours can be categorized as either "cool" or "warm," as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for an <u>Interactive Healthcare Robot?</u>

Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

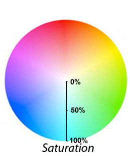
The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.



Which level of brightness would you prefer for an <u>Interactive Healthcare Robot</u>?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for an <u>Interactive Healthcare Robot</u>?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures

Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for an <u>Interactive Healthcare Robot</u>?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

If other, specify:

4) Shape

Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for an <u>Interactive Healthcare Robot</u>?

Animal-Like Robot	Human-Like Robot	Machine-Like Robot	Other
☐	☐	☐	

5) Voice

Which voice would you prefer for an <u>Interactive Healthcare Robot</u>?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Domestic Utility Robot:

Domestic utility robots are designed to do housework for human. For example, robots could wash dishes, wash clothes, cleaning, cooking, guard people's home, etc.

General Opinions:

6) In general, do you think that governments, research organizations, or companies should spend time and money on developing Domestic Utility Robots?

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

7) Do you think that Domestic Utility Robots will become more common in people's daily lives in the near future?

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

8) In what way do you think that Domestic Utility Robots could impact your life?

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Domestic Utility Robots may impact your life:

9) Do you think that, in general, there are risks involved with adopting Domestic Utility Robots in society?

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

10) Do you personally feel that there would be risks involved with deploying Domestic Utility Robots yourself?

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of domestic utility robots. Please carefully consider and rate your opinions

1) Cleaning Robot: These robots could clean floors, wash dishes, wash and fold clothes.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

2) Cooking Robot: These robots could range from simply helping to chop vegetables or mix ingredients, or could prepare entire meals.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

3) Personal Security Robots: These robots could help monitor your home and property for intruders while you are away. Some robots can recognize people and send alerts to police, and others can engage potential intruders.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

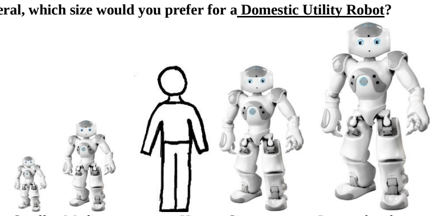
Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

Appearance:

1) Size

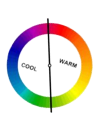
In general, which size would you prefer for a Domestic Utility Robot?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour

Colours can be categorized as either "cool" or "warm," as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for a Domestic Utility Robot?

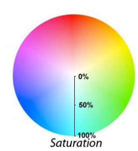
Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.

Which level of brightness would you prefer for a Domestic Utility Robot?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for a Domestic Utility Robot?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures

Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for a Domestic Utility Robot?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

If other, specify:

4) Shape

Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for a Domestic Utility Robot?

Animal-Like Robot	Human-Like Robot	Machine-Like Robot	Other
☐	☐	☐	

5) Voice

Which voice would you prefer for a Domestic Utility Robot?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Military Robot:

Military robot has been used to replace people to do dangerous jobs or to access inaccessible areas. For example, bomb disposal robot, reconnaissance robot, combat and battle robot.

General Opinions:

1) In general, do you think that governments, research organizations, or companies should spend time and money on developing Military Robots?

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

2) Do you think that Military Robots will become more common in people's daily lives in the near future?

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

3) In what way do you think that Military Robots could impact your life?

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Military Robots may impact your life:

4) Do you think that, in general, there are risks involved with adopting Military Robots in society?

very risky	risky	moderately risky	slightly risky	not at all risky
☐	☐	☐	☐	☐

5) Do you personally feel that there would be risks involved with deploying Military Robots yourself?

very risky	risky	moderately risky	slightly risky	not at all risky
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of military robots. Please carefully consider and rate your opinions

1) Dangerous Task Robot: These robots are designed to perform dangerous tasks, such as testing and disposing of bombs, entering damaged buildings which may fall, and so forth.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

2) Reconnaissance Robot: These robots can travel long distances to remote areas or enter enemy territory, to monitor land for weather, other's activities, and so on. They could also provide mapping and sensor data in real time.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

3) Combat or Battle Robots: These robots can engage battle when necessary to fight in the place of human soldiers.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

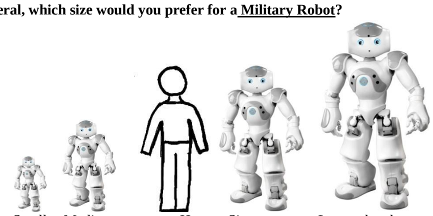
Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

Appearance:

1) Size

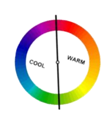
In general, which size would you prefer for a Military Robot?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour

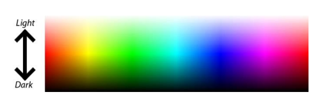
Colours can be categorized as either "cool" or "warm," as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for a Military Robot?

Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

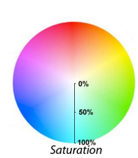
The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.



Which level of brightness would you prefer for a Military Robot?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for a Military Robot?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures
Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for a <u>Military Robot</u>?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

4) Shape
Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for a <u>Military Robot</u>?

Animal-Like Robot	Human-Like Robot	Machine-Like Robot	Other
☐	☐	☐	

5) Voice

Which voice would you prefer for a <u>Military Robot</u>?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Urban Search and Rescue Robot:

Urban Search and Rescue robots are designed to aid rescue workers during accidents, disasters, searching for missing people, etc.

General Opinions:

1) In general, do you think that governments, research organizations, or companies should spend time and money on developing Urban Search and Rescue Robots?

definitely should	probably should	no opinion / don't care	probably should not	definitely should not
☐	☐	☐	☐	☐

2) Do you think that Urban Search and Rescue Robots will become more common in people's daily lives in the near future?

very common	common	moderately common	slightly common	not at all common
☐	☐	☐	☐	☐

3) In what way do you think that Urban Search and Rescue Robots could impact your life?

very negative	negatively	little or no influence	positively	very positively
☐	☐	☐	☐	☐

Comment for your above opinion on how Urban Search and Rescue Robots may impact your life:

4) Do you think that, in general, there are risks involved with adopting Urban Search and Rescue Robots in society?

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

5) Do you personally feel that there would be risks involved with deploying Urban Search and Rescue Robots yourself?

very risky	**risky**	**moderately risky**	**slightly risky**	**not at all risky**
☐	☐	☐	☐	☐

If you feel that there are some risks, please list 1~5 risks that immediately come to mind:

Feel free to repeat previous answer, such as "same as above"

Usage Scenarios:

Below are some examples of different types of urban search and rescue robots. Please carefully consider and rate your opinions

1) Exploration Robot: These robots could access dangerous areas or places inaccessible to people, or do constant search over large areas, for example by going under rubble or into caves, flying over forest fires, or patrolling large areas of open water.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

2) Team-Member Robot: These robots work alongside human team members, for example, carrying injured people, helping hold equipment, and so forth.

Do you think this function is useful?

very useful	useful	moderately useful	slightly useful	not at all useful
☐	☐	☐	☐	☐

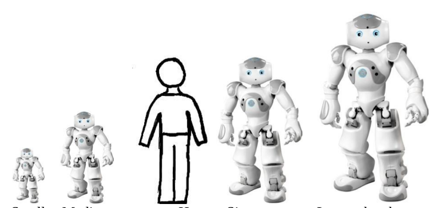
Would you consider buying this kind of robot?

very likely	likely	moderately likely	slightly likely	not at all lightly
☐	☐	☐	☐	☐

Appearance:

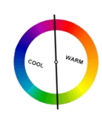
1) Size

In general, which size would you prefer for an <u>Urban Search and Rescue Robot</u>?



Small	Medium	Human-Size	Larger than human
☐	☐	☐	☐

2) Colour
Colours can be categorized as either "cool" or "warm," as shown in the image below: the black line separates the colours into the cool group on the left and warm group on the right. Colours close to the black line are more neutral.



Which colour tone would you prefer for an <u>Urban Search and Rescue Robot?</u>

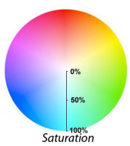
Cool	Somewhat Cool	Neutral	Somewhat Warm	Warm
☐	☐	☐	☐	☐

The lightness of a colour is how bright it is: the image bellow shows the spectrum of colours with lighter ones near the top, and darker ones near the bottom.

Which level of brightness would you prefer for an <u>Urban Search and Rescue Robot</u>?

Bright	Somewhat Bright	Neutral	Somewhat Dark	Dark
☐	☐	☐	☐	☐

The saturation of a colour is how colourful it is. Unsaturated colours are washed out, or pastel, as shown in the image below.



Which level of saturation would you prefer for an Urban Search and Rescue Robot?

Saturated	Somewhat Saturated	Neutral	Somewhat Unsaturated	Unsaturated
☐	☐	☐	☐	☐

3) Textures
Robots can be made from various materials, and in particular, their outer layer can be made in a range of ways. Organic includes fabric, fur or leather.

Which kind of texture would you prefer for an Urban Search and Rescue Robot?

Organic	Rubber	Plastic	Metal	Other
☐	☐	☐	☐	

4) Shape
Some robots are made to look like animals, some are made to look human-like, and others are purely machine like and functional in appearance. Examples are as follows:

		
Animal-Like Robot	Human-Like Robot	Machine-Like Robot

Which shape would you prefer for an Urban Search and Rescue Robot?

Animal-Like	Human-Like	Machine-Like	Other

Robot	Robot	Robot
☐	☐	☐

5) Voice

Which voice would you prefer for an Urban Search and Rescue Robot?

Female Voice	Male Voice	Gender Neutral Voice	Computer Synthesized
☐	☐	☐	☐

Part 3: General Thoughts

If you have any more thoughts about robots, and their uses and applications, please feel free to write them here:

A.2 The Results from Quantitative Analysis

We present all quantitative results about people's attitudes toward robotic development and their preferences for robotic physical design.

		robot type (median scores reported)					
		domestic	military	educational	healthcare	entertain.	USAR
	question posed	M / F	M / F	M / F	M / F	M / F	M / F
attitudes toward robot purpose	In general, do you think that governments, research organizations, or companies should spend time and money on developing robots? (1 definitely should, 5 definitely should not)	2(-) / 2(+) **	1 / 2	2 / 2	2 / 2	2 / 3 ***	1 / 1
	Do you think robots will become more common in peoples' daily lives in the near future? (1 very common, 5 not at all)	2 / 2	2 / 2	2 / 2	3 / 3	3 / 3	2 / 2
	In what way do you think that robots could impact your life? (1 very positive, 5 very negatively)	2 / 2	2 / 3	2 / 3	3 / 3	2 / 3 *	2 / 2
	Do you think that, in general, there are risks involved with adopting robots in society? (1 very risky, 5 not at all risky)	4 / 4	2 / 3	4 / 3	3 / 4	4(+) / 4(-) ***	4 / 4
	Do you personally feel there would be risks involved with adopting robots yourself? (1 very risky, 5 not at all risky)	4(+) / 4(-) **	2 / 3	4 / 4	4 / 3.5	5 / 4 ***	4 / 3.5
attitudes toward robot design	In general, which size would you prefer for a robot? (1 small 4 larger than human-size 5 no opinion)	2 / 2	3 / 3	3 / 3	3 / 3	2 / 2	3 / 3
	Which color tone would you prefer for a robot? (1 cool, , 6 no opinion)	3 / 3	4 / 3	3 / 4 *	4 / 4	4 / 4	4 / 3
	Which level of lightness would you prefer for a robot? (1 light, 5 dark, 6 no opinion)	2 / 3	4 / 4	2 / 3	2 / 3	3 / 3	3(-) / 3(+) *
	Which level of saturation you would prefer for a robot? (1 colorful, 5 faded, 6 no opinion)	3 / 3	4 / 3	3 / 3	3 / 3	3 / 3	3 / 3
	Which kind of texture would you prefer for a robot? (O organic, fabric, fur, etc., I inorganic, plastic, metal, etc., N=no opinion)	I 60% / I 64%	I 64% / I 78%	I 59% / I 46%	I 50% / I 50%	O 40% / I 36%	I 70% / I 62%
	Which shape would you prefer for a robot? (A animal-like, H=human-like, M= machine-like, N= no opinion)	H 50% / M 45%	M 41% / M 59%	H 69% / H 73%	H 78% / H 64%	H 61% / H 39%	H 45% / H 46%
	Which voice style would you prefer for a robot? (F female, M male, G gender neutral human, S computer synthesized N no opinion)	G 27% / G 31%	N 41% / G 48%	G 40% / G 56%	F 41% / G 57%	N 37% / G 33%	G 27% / G 43%

Figure A.1: Questions and Results about Attitudes Toward Robotic Development and Design (mann-whitney tests for ordinal data (median reported) and chi-squared tests for nominal data (mode reported); for significant results with the same median, relationship denoted by (+) larger and (-) smaller based on mean ranks. *p<.05, **p<.01, ***p<.005)

Appendix B

Supporting Data for The Laboratory Study

We provide all questionnaires used in our in-lab study, as well as our coding guidelines for the two researchers (Chapter 5).

B.1 Questionnaires

It includes one demographic questionnaire and two perception-related questionnaires.

PID_______________

Pre-study Questionnaire – demographic questionnaire

1) **What is your biological sex?**
   A. Woman
   B. Man
   C. Intersex

2) **What is your age?**
   A. Under 18
   B. 18-22 years old
   C. 23-27 years old
   D. 28-32 years old
   E. 33-37 years old
   F. Above 38 years old

3) **If you are currently a student, what is your (potential) major?**

   ____

4) **What is your mother tongue? If it is not English, would you consider your English to be equivalent to native speaker?**

   ____

5) **Which cultural or national identity do you most identify with? (e.g., Canadian, Chinese, Indian, etc.)**

   ____

PID: ______________

Intermediate Questionnaire

Although you only had minimal interaction with Taylor, please to the best of your ability circle your opinion on Taylor's personality traits as listed below. If you cannot fully reflect on the trait, please rate as best you can based on your impression of Taylor：

Taylor seems to be……

	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
sensitive	1	2	3	4	5	6	7
assertive	1	2	3	4	5	6	7
hard-hearted	1	2	3	4	5	6	7
friendly	1	2	3	4	5	6	7
affable	1	2	3	4	5	6	7
cold	1	2	3	4	5	6	7
romantic	1	2	3	4	5	6	7
organized	1	2	3	4	5	6	7
dominant	1	2	3	4	5	6	7
empathetic	1	2	3	4	5	6	7
has leadership skills	1	2	3	4	5	6	7
cooperative	1	2	3	4	5	6	7
tough	1	2	3	4	5	6	7
aggressive	1	2	3	4	5	6	7
determined	1	2	3	4	5	6	7
sentimental	1	2	3	4	5	6	7
affectionate	1	2	3	4	5	6	7
family-oriented	1	2	3	4	5	6	7
confident	1	2	3	4	5	6	7
speaks own mind	1	2	3	4	5	6	7

PID: _____________

sincere	1	2	3	4	5	6	7
delicate	1	2	3	4	5	6	7
polite	1	2	3	4	5	6	7
authoritative	1	2	3	4	5	6	7

Based on your interactions with and impressions of Taylor, please indicate the extent to which you think that Taylor or a future improved Taylor would be well suited to the following tasks:

	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
handcrafting	1	2	3	4	5	6	7
repairing technical equipment	1	2	3	4	5	6	7
elderly care	1	2	3	4	5	6	7
patience care	1	2	3	4	5	6	7
after-school tutoring	1	2	3	4	5	6	7
servicing equipment	1	2	3	4	5	6	7
preparing meals	1	2	3	4	5	6	7
household maintenance	1	2	3	4	5	6	7
transporting goods	1	2	3	4	5	6	7
childcare	1	2	3	4	5	6	7
guarding a house	1	2	3	4	5	6	7
operating machinery	1	2	3	4	5	6	7

PID: _____________

If you had to work with Taylor or a future improved Taylor on a collaborative task, how useful do you think that Taylor would be for?

	very useless	useless	somewhat useless	neutral	somewhat useful	useful	very useful
a math task	1	2	3	4	5	6	7
a verbal task	1	2	3	4	5	6	7

PID: _____________

Post Test Questionnaire

Although you only had minimal interaction with Taylor, please to the best of your ability circle your opinion on Taylor's personality traits as listed below. If you cannot fully reflect on the trait, please rate as best you can based on your impression of Taylor:

Taylor seems to be……

	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
sensitive	1	2	3	4	5	6	7
assertive	1	2	3	4	5	6	7
hard-hearted	1	2	3	4	5	6	7
friendly	1	2	3	4	5	6	7
affable	1	2	3	4	5	6	7
cold	1	2	3	4	5	6	7
romantic	1	2	3	4	5	6	7
organized	1	2	3	4	5	6	7
dominant	1	2	3	4	5	6	7
empathetic	1	2	3	4	5	6	7
has leadership skills	1	2	3	4	5	6	7
cooperative	1	2	3	4	5	6	7
tough	1	2	3	4	5	6	7
aggressive	1	2	3	4	5	6	7
determined	1	2	3	4	5	6	7
sentimental	1	2	3	4	5	6	7
affectionate	1	2	3	4	5	6	7
family-oriented	1	2	3	4	5	6	7
confident	1	2	3	4	5	6	7
speaks own mind	1	2	3	4	5	6	7

PID: _____________

sincere	1	2	3	4	5	6	7
delicate	1	2	3	4	5	6	7
polite	1	2	3	4	5	6	7
authoritative	1	2	3	4	5	6	7

Based on your interactions with and impressions of Taylor, please indicate the extent to which you think that Taylor or a future improved Taylor would be well suited to the following tasks:

	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
handcrafting	1	2	3	4	5	6	7
repairing technical equipment	1	2	3	4	5	6	7
elderly care	1	2	3	4	5	6	7
patience care	1	2	3	4	5	6	7
after-school tutoring	1	2	3	4	5	6	7
servicing equipment	1	2	3	4	5	6	7
preparing meals	1	2	3	4	5	6	7
household maintenance	1	2	3	4	5	6	7
transporting goods	1	2	3	4	5	6	7
childcare	1	2	3	4	5	6	7
guarding a house	1	2	3	4	5	6	7
operating machinery	1	2	3	4	5	6	7

PID: _____________

If you had to work with Taylor or a future improved Taylor on a collaborative task, how useful do you think that Taylor would be for?

	very useless	useless	somewhat useless	neutral	somewhat useful	useful	very useful
a math task	1	2	3	4	5	6	7
a verbal task	1	2	3	4	5	6	7

Taylor seemed to be…

rather female			gender-neutral			rather male
1	2	3	4	5	6	7

Feel free to add any comments about the robot.

____

____

____

____

____

____

____

____

____

____

____

END

B.2 Coding Guidelines for Video Analysis

We present the full coding guidelines regarding people's politeness, relaxation and engagement.

Coding Guidelines

In this research, we explore how men and women interact with a robot in a specific interaction scenario and analyse gender differences/impacts from the three aspects: if people are being polite to the robot in conversation; if people are relaxed while talking to the robot; if people are able to engage in a conversation with the robot. In my experiment, to evoke the conversation, the robot discussed 3~4 fixed topics in an allotted three minute time period with participants and we recorded this interaction for the analysing purpose.

<table>
<tr><td colspan="2">Politeness: Previous work showed that women are easier to be influenced by others, I want to explore if women show more politeness than men do when the robot is being polite.</td></tr>
<tr><td colspan="2">Hypotheses: when interacting with a polite robot, female participants will be more polite than male participants.</td></tr>
<tr><td colspan="2">Baseline for judging politeness: similar standards for politeness in human-human interaction – when people interact with robots, they show good manners and behave in a way that is socially correct and not rude to the robots.</td></tr>
<tr><td>Positive (polite):
standard:
participants give polite responses to the robot's questions/requests during the conversation.</td><td>Negative (rude):
standard:
participants ignore the robot's questions/requests during the conversation</td></tr>
<tr><td>examples for short instances:
Code PP</td><td>examples for short instances:
Code NP</td></tr>
<tr><td>PP1: give polite responses to robot politeness: when robot says "nice talking to you/nice to meet you," "thank you/thanks," "…please...," participants give responses politely.
PP2: polite to robot's requirements: e.g., "can we please talk about something else," "could you speak a bit louder," participants agree.
PP3: participants are being polite actively: asking the robot's feeling actively, such as "how are you today," "Hi," etc., before the robot starts talking; remember robot's name; say "thanks/ sorry/please" to the robot actively.
PP*: some cases may be not covered by the upper instances, but it's clear that the participant is being polite. Eg., people give positive feedback about the robot's performance.</td><td>NP1: ignore robot's politeness: robot says "thank you," "nice talking with you," etc., and participants don't give any response or give an unusually short response; participants changed topics for personal needs
NP2: ignore what the robot questions/requests
NP3: participants are distracted, e.g., look around, play with their cellphone. Note, if the robot/people not talking with each other, it is okay to look around.
NP*: some case not being covered by the upper instances, but it's clear that the participant is being rude. Eg., looking around while talking with robot (extreme)</td></tr>
</table>

<table>
<tr><td colspan="2">Relaxation: as the previous study shows, women tend to be more fearful of new technology. I would like to explore if there are some differences between men and women in terms of relaxation/nervousness during the conversation.</td></tr>
<tr><td colspan="2">Hypothesis: women are more nervous than men when they interact with a robot</td></tr>
<tr><td colspan="2">Baseline for judging nervousness: by observing participants' facial expression or body language, we may tell that the participants are nervous about something, or they are quite calm and less tense or worried.</td></tr>
<tr><td>Positive (relaxed):
standard:
observing participants' facial expression and body language to see if they are calm and less tense or worried</td><td>Negative (nervous):
standard:
observing participants' facial expression and body language to see if they are nervous or worried about something.</td></tr>
<tr><td>examples for short instances:
Code PR</td><td>examples for short instances:
Code NR</td></tr>
<tr><td>PR1: relaxation showed by body language:
(1) sit comfortably, like put one leg on the other/put their feet on the chair/use their hand to support their chin (maximum 3 per video) (2)approach the robot, observe the robot from different angles;
PR2: relaxation showed by facial expression:
smiling naturally or laugh out loud
PR3: relaxation conveyed by verbal expression:
talk with or ask robot questions actively to continue the conversation, but do not show the desire/need to know more about the robot
PR*: instances clearly show participants are relaxed.</td><td>NR1: nervousness showed by body language:
(1) fidget with their hands or clinched hands; (2) sitting rigid/straight;(3) moving while biting lips or having some hand movements
NR2: nervousness showed by facial expression:
(1) avert eyes from the robot (avoid eye contact); (2) smile or laughing nervously; embarrassed laugh
NR3: nervousness conveyed by verbal expression:
take a long time to answer a question as if they are thinking or unsure (not bored or distracted)
NR*: instances clearly show participants are nervous. Eg., move away or keep distance from the robot</td></tr>
</table>

<table>
<tr><td colspan="2">Engagement: according to our online survey, males tend to be more positive about robot's development and impacts. In this exploratory study, we want to explore if men are more engaging in human-robot interaction than women.</td></tr>
<tr><td colspan="2">Hypothesis: men are more engaged in human-robot interaction than women</td></tr>
<tr><td colspan="2">Baseline for judging engagement: participants actively talk to the robot, and are willing to answer robots questions and ask questions back to know more about the robot, in addition to length of utterance</td></tr>
<tr><td>Positive (engaged):
standard:
participants actively talk to the robot, and ask questions back to know more about the robot</td><td>Negative (detached):
standard:
only answer the robot's questions briefly, don't ask the robot question actively</td></tr>
<tr><td>examples for short instances:</td><td>examples for short instances:</td></tr>
</table>

Code PE	Code NE
PE1: <u>engagement showed by body language</u>: lean in/towards the robot **PE2:** <u>engagement showed by facial expression:</u> observed extreme facial expression, or changes of facial expression that indicates participant's engagement. **PE3:** <u>conveyed by verbal expression:</u> (1) participants put thought to robot's questions and answer with full sentences, i.e. participants mention multiple personal habits when the robot asks "what do you do in your spare time?" (2) ask the robot questions actively, passionate to know more about the robot (notes, if people ask questions because the robot asked for it, doesn't count as "actively"); asking about robot's "personal" information **<u>PE*</u>:** instances clearly show participants are engaged, such as take more than 15s to answer a question.	**NE1:** <u>showed by body language</u>: looking at a watch or checking time **NE2:** <u>showed by facial expression:</u> looks uncomfortable or annoyed somehow; slightly looking around; no facial expression changes for a long time. **NE3:** <u>conveyed by verbal expression:</u> give very short answer "yes/no" to robot's questions **<u>NE*</u>:** instances clearly show participant is not engaged; such as participants spend less than 5s to those "what" questions, or looked away from the robot while answering questions.

1. Coding boundary: for a continuous behavior, after add one code, counting from the end of an instance and then count 15~20s for politeness, relaxation and engagement.

2. How to deal the different subcode under the main codes PE, PR, PP? If there are different codes under PE happened within the time boundary, we need to code all of them.

3. When you observe PP1 & PP3 at same time, just add PP3. For PP2, whenever people takes robot's suggestions/requests, add PP2. However, be aware of the time boundary.

4. For PE3 and PR3, although it all can be added if people ask questions actively. There are some nuances:

(1) people show their engagement (passionate, emotional) and relaxation when they ask questions, add both codes.

(2) people just ask questions as a manner or just for keeping the conversation, only add PR3

(3) people doesn't feel relax, but they want to know more about the robot by asking question, only add PE3.

5. For each time clip, we maximum add two subcodes for each main variable.

6. For dramatic behaviors that do not fall under any coding categories we have, ignore them, such as the behaviors indicate that the participant was embarrassed.

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