Examining Diverse Gender Dynamics in Human-Robot Interaction: Trust, Privacy, and Safety Perceptions

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ABSTRACT

This research adopts a multidisciplinary approach, synthesizing insights from psychology, technology, and ethics to unravel the intricate threads of diverse gender perceptions regarding trust-building, privacy considerations, and safety concerns in Human-Robot Interaction (HRI). Our study contributes to a holistic understanding of HRI dynamics, providing valuable insights for designing robots to assist individuals with their Activities of Daily Living (ADL) at home, including tasks such as preparing their daily meals independently. This study delves into the correlation between robot failures and gender perceptions of trust, privacy, and safety when a human communicates with a robot in a natural way by using unstructured speech. In this approach, the user commands the robot conversationally using natural spoken language to fetch cooking-related items in a research lab's mocked-up kitchen. With a participant pool of 35 adults (13 females with an average age of 35.58 ± 12.06 and 22 males with an average age of 35.68 ± 15.35), Kendall's Tau correlations are employed for statistical analysis, offering a comprehensive investigation into the intricate interplay of gender, interaction methods, and perceptions in the realm of human-robot dynamics.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

Human-Robot Interaction, Trust, Gender, Usability, Ethical Considerations

ACM Reference Format:
Manizheh Zand, Krishna Kodur, Sean Banerjee, Natasha Banerjee, and Maria Kyrarini. 2024. Examining Diverse Gender Dynamics in Human-Robot Interaction: Trust, Privacy, and Safety Perceptions. In *The PErvasive Technologies Related to Assistive Environments (PETRA) conference (PETRA '24), June 26–28, 2024, Crete, Greece.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3652037.3652078

PETRA '24, June 26–28, 2024, Crete, Greece

ACM ISBN 979-8-4007-1760-4/24/06
https://doi.org/10.1145/3652037.3652078

1 INTRODUCTION

As the baby boomer generation approaches retirement age, it is expected to precipitate in a potential 73% increase in the population over 65 by 2029 [11]. It is imperative to underscore that a pivotal indicator of societal well-being concerning aging populations lies in the capacity of individuals to independently execute their Activities of Daily Living (ADLs) [9]. This aptitude for ADL performance is the paramount metric for assessing older adults' autonomy in daily living. Furthermore, the World Health Organization (WHO) has emphasized that the criteria for evaluating individuals' health should extend beyond mortality and morbidity metrics, encompassing their ability to sustain an autonomous living [21]. Robotic systems could provide a way to sustain autonomous and independent living [16].

Interactions are inherently multifaceted and subject to a multitude of determinants, including but not limited to communication styles and preferences, as well as cultural and societal norms that delineate the thresholds of comfort experienced by individuals. For instance, Claes [8] notes that gender indicates psychological, social, and cultural differences. The author also adds that females are more inclined to apply hedges, hesitations, tag questions, and verbosity linguistic features in their linguistic communications. Woods et al. [22] identified a high correlation based on how genders rated their personality versus the robot's personality. Their study recruited 28 participants, students, faculty, and researchers, 50% male and 50% female, from the University of Hertfordshire. They interacted with a human-sized robot in a simulated living room scenario in two tasks relevant to a home setting. Woods et al. found a number of significant correlations were found between participant gender and ratings of their own personality traits and ratings of robot personality. For example, there was a positive correlation between males rating their anxiety versus the robot. Whereas in female participants, rating themselves as more assertive was positively correlated to rating the robot as more dominant.

The statement from Biereman et al. [4] suggests that differences in the learning and adaptation processes may be observed distinctly between females and males. According to the authors, females tend to favor learning through relationships, critical reflection, and mentorship, while males lean towards learning through engaging in challenging assignments. These factors can significantly shape the manner in which these demographic groups engage with robotic entities. Consequently, it is imperative to acknowledge the multifarious dimensions and determinants that underpin gender-based

behavior, impacting individuals' perceptions and levels of trust in robotic systems, imbuing their interactions with the sentiment of comfort and reassurance.

In our earlier research [15], we delved into the nuanced realm of users' communication style preferences with robots, juxtaposing the structured (following a script) against the unstructured (engaging conversationally) interaction paradigms. The findings, substantiated by compelling statistical evidence, pointed towards a prevailing inclination for unstructured communication among users. Notably, while not unearthing statistically significant evidence indicating a detrimental impact on individual perceptions of robots due to experiences of robot failures, our study encountered an alternative perspective through Graaf et al.'s insightful investigations [10].

Graaf et al .[10] extensively reviewed prior research on how individuals interpret Autonomous Intelligent Systems, particularly robots, employing both theoretical analysis and experimental approaches. One notable observation was the tendency of individuals to attribute errors to robots, even in situations where the robots performed correctly, emphasizing the crucial role of effective communication in mitigating such misinterpretations. The authors underscored that users develop and refine their trust in robots based on their cumulative experiences, particularly when the system effectively communicates its behaviors.

Moreover, the studies of Graaf et al. [10]. spotlighted the complex dynamics of human-robot interaction and trust-building. The authors highlighted the significance of designing transparent communication protocols within human-robot interaction, advocating for a nuanced understanding of intentional and unintentional behaviors exhibited by autonomous intelligent systems. This distinction, they argued, is vital for cultivating trust and positive user perceptions. The synthesis of our findings and Graaf et al.'s [10]. insights reinforces the imperative nature of transparent communication in shaping the evolving landscape of human-robot interaction.

This research paper delves into the intricate dynamics of Human-Robot interaction. The novelty of this research paper is to understand the gender perception in HRI in creating an inclusive and adaptable system to a diverse range of persons' preferences and needs, regardless of gender, to assist them with their ADLs, such as preparing daily meals. To achieve that, the following hypothesis will be investigated. **Hypothesis:** Gender Diversities play a significant role in how individuals perceive trust and safety when interacting with robots, with variations in trust, privacy, and safety perceptions among genders.

The rest of the paper is organized as follows: Section 2 will delve into state-of-the-art research, providing a comprehensive overview of existing studies and advancements. Following this, Section 3 will detail the experimental methodology, encompassing scenarios, and setups employed in the study. Section 4 will present and analyze the results obtained from the experimentation. Subsequently, Section 5 will engage in discussions, offering insights and interpretations of the findings. The final section will encapsulate the conclusion drawn from the study and outline potential avenues for future work.

2 RELATED WORK

Akalin et al. [1] underscore the significance of safety perception, examining it through six key factors: comfort, predictability, sense of control, transparency, trust, and experience/familiarity. The study involved twenty-seven participants, comprising 17 females and 10 males, aged 20 to 37, recruited via social media platforms and flyers. The research utilized the Pepper robot, a social humanoid proficient in intelligent conversation using natural speech. Participants engaged with the robot in quiz games, where the robot's speech was controlled through a Wizard of Oz method, followed by completing a survey regarding their interactions with the robot. During the study, participants encountered robot errors either at the beginning or end, with surveys and games completed in both scenarios. Two setups were employed, both starting with a baseline. In one setup, the study progressed from Baseline to the Sense of Control, Comfort, Predictability, and Trust, with the robot exhibiting faults toward the end. In the other setup, the study followed the Baseline with the Predictability, Trust, Sense of Control, and Comfort, while the robot demonstrated faults at the beginning. The study's findings indicated that the Sense of Control showed a correlation with Perceived Safety at 72%, Trust correlated with Perceived Safety at 67%, and Comfort exhibited a correlation with Perceived Safety at 78%.

Lei et al. [17] contribute to this understanding by exploring the influence of gender on perceptions in human-robot interactions. Sixty undergraduate and graduate students who did not major in computer science, artificial intelligence, and automation. Two persons of the same gender who were strangers were teamed up with Noa, a gender-neutral robot operated by Wizard of Oz, to discuss the Desert Survival problem. The authors emphasized that social interaction, technology acceptance, and anthropomorphic behaviors are pivotal in shaping a robot's role. Their findings indicate that social attributes primarily influence female perceptions, whereas male perceptions are more closely tied to the task. Moreover, a study by Schermerhorn et al. [18] showed that females tended to view robots as more machine-like, while males perceived them as more human-like. The study consisted of 24 males and 23 females (undergraduate students taking engineering, general education, and Psychology courses). The study consisted of three stages: pre and post-surveys and two simple arithmetic tasks done by the robot. The authors added that possible reasons might be the robot's having a male voice or pre-existing perception based on gender.

Friedman et al.[7] interviewed twenty-nine male undergraduate computer science majors on how they view computer errors; 21% of them consistently blamed computer systems for errors. Hinds et al. [12] studied 292 college student participants with 59% women, and found out that participants relied on human partners versus robot partners (Mean = 4.73, Standard Deviation = 0.56). It is very challenging for humans to understand how robots comprehend information. Graaf et al. [10] mentioned that people interacting with Autonomous Intelligence Systems (AIS) create mental models to comprehend AIS behavior to trust the system, which may have a risk of creating incorrect models. Moreover, it is emphasized that errors and physical and psychological hazards can arise from under or over-trusting the robot's "intelligence" system. This underscores

the need for a balanced understanding of trust in robot interactions to ensure safety and efficacy.

Examining how individuals of diverse genders interact politely with robots is crucial for comprehending user expectations and experiences in HRI. These interactions unveil the intricate interplay among gender norms, robot behavior, and user satisfaction, shaping the trajectory of socially competent and considerate robots. In a study by Strait et al. [19], an experiment was conducted to investigate the effects of robot politeness on individuals of different genders. Participants were tasked with drawing a koala, and a Wizard-of-Oz behind the robot provided either positive or negative instructions for the drawing process. The findings revealed that females tended to rate the robot more positively in politeness than males.

Another study by Alexander et al. [3] explored gender differences in asking for help from robots. There were 48 participants, 24 males and 24 females. The robot in the study was Keepon, a small yellow robot, sitting with four degrees of freedom with cameras and a microphone. The participants randomly got the robot with a male or female voice, which created four different cases based on the participants' gender. The participants had to solve Sudoku puzzles. The experiment concluded that males were more inclined to seek assistance from robots than females. These insights are particularly valuable as they shed light on the reasons behind varying help-seeking behaviors among diverse genders.

In our previous research work [15], we derived two main conclusions: firstly, users show a preference for unstructured forms of communication when interacting with robots; secondly, we observed that an individual's perception of a robot remains consistent despite the robot's errors. However, this leads to an intriguing question: "Are there additional factors influencing how diverse genders perceive the robot differently?" This question suggests a need for further exploration of these factors that could deepen our understanding of the nuances in gender-specific interactions with robots.

3 EXPERIMENTAL METHODOLOGY

This research continues earlier work conducted, as documented in [15]. The initial study primarily focused on exploring the human perspective regarding robots capable of comprehending speech commands and executing corresponding actions in a kitchen-like environment. Utilizing the table as the designated cooking space equipped with a stove, water, and essential cooking tools. Additional ingredients, including bell peppers, butter, carrots, cheese, chili, corn, garlic, green beans, mushrooms, pasta, and tomato sauce, are placed on the counter, out of immediate reach. The subject was seated behind a table, giving the robot commands via structured and unstructured methods. In this current phase, the research extends its scope to investigate whether HRI exhibits diverse gender patterns and variations. Figure 1 shows a user (male or female) command robot via structured and unstructured speech. A comprehensive dataset was collected, comprising survey responses, transcriptions of participant-issued commands directed towards the robot, and records of instances where the robot encountered errors. The analysis of participant interactions with the robot revealed various intriguing behaviors, such as gender-based Trust, Privacy, and Safety Dynamics.

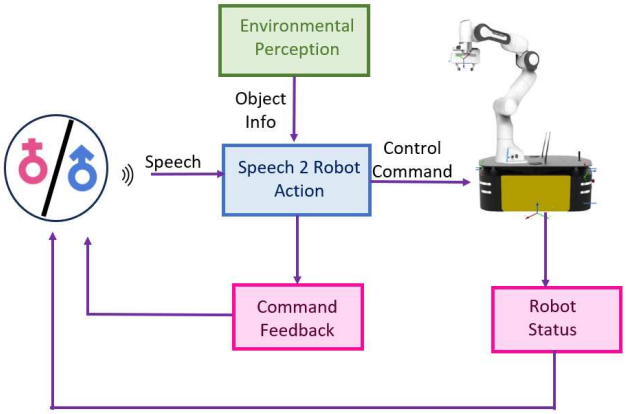

Figure 1: System Architecture for Collaborative Cooking with a Robot

3.1 Recruiting and Experiment Protocol

The recruitment process adhered to a protocol approved by the Institutional Review Board (IRB) protocol number 23-02-1902 and involved enlisting 35 participants. Among them, 13 participants identified themselves as females, constituting 37.14% of the cohort, with an average age of 35.58 ± 12.06. The remaining 22 participants identified themselves as males, representing 62.86% of the cohort, with an average age of 35.68 ± 15.35. The overall average age of the participant pool stood at 35.64 ± 14.08.

Participants were recruited from Santa Clara University, encompassing students, staff, and visitors. Prior to their participation in the study, each participant received a comprehensive letter of consent via email. This document provided detailed information about the study, elucidating the nature of the data collected and the stringent measures to ensure data storage and processing confidentiality.

Upon their arrival on the study day, each participant was guided to a table where they proceeded to sign both the consent and optional demographic forms. The robot's speed was deliberately reduced to 0.05m/s to prioritize a safe environment for user-robot interaction. This precautionary measure aimed to mitigate potential risks associated with the robot's movement. By eliminating physical safety, we focussed our study on psychological safety [10].

The study session was divided into two distinctive sections: the structured method involving pre-defined commands and the unstructured method involving unscripted sentences. To maintain impartiality and address potential order effects, the sequence of these methods was systematically altered for successive subjects, ensuring a balanced and unbiased approach to the experimental design.

Subsequent to each method, participants were prompted to complete the System Usability Scale (SUS) survey [6]. Additionally, participants were presented with the Human-Robot Collaboration

Questionnaire (HRCQ), as illustrated in Table 1. This questionnaire aimed to gather insights into participants' perceptions of safety, ethical considerations, and the overall usefulness of the system.

It is noteworthy that, based on findings from previous research [13], participants expressed a preference for the unstructured communication method.

Table 1: The Likert Scale Statements for the Human-Robot Collaboration Questionnaire.

	Likert Scale Based Statements
Perceived Usefulness	I accomplished the given tasks rapidly.
	I accomplished the given tasks successfully.
Perceived Safety and Trust	The robot's actions were predictable.
	I felt safe using the robot.
	I trusted the robot's suggestions.
Perceived Ease of Use	I found the robot easy to use.
	The robot learned how to assist me.
	The robot met my expectations.
Perceived Interaction	I had to learn more about robots in order to be able to interact with the system.
	I felt my voice volume was normal.
	I had to speak slowly to interact with the robot.
Ethical Considerations	It is acceptable for the robot to have much information about the user.
	I am concerned about my privacy when using the robot.
	I should have full control of when and how the robot will assist me.

4 EXPERIMENTAL RESULTS

The current research is focused on unstructured methods of communication.

Having established the metrics, expansion upon the hypotheses declared in Section 1 follows as outlined.

Hypothesis: Gender Diversities play a significant role in how individuals perceive trust and safety when interacting with robots, with variations in trust, privacy, and safety perceptions among genders.

The P-value associated with Kendall's Tau correlation should be less than 0.05 to reject the null hypothesis and accept the alternative hypothesis. Additionally, the application of the Bonferroni correction [5] is implemented when necessary. The categorization of correlation strengths (Corr) into weak, moderate, and strong follows Akoglu's framework [2], where these classifications are delineated as: $0.2 < |Corr| \leq 0.3$ for weak correlation, $0.3 < |Corr| \leq 0.4$ for moderate correlation, and $|Corr| > 0.4$ for strong correlation.

Statistically significant correlations from the survey questions of all sections "Perceived Usefulness", "Perceived Safety and Trust", "Perceived Ease of Use", "Perceived Interaction" and "Ethical Considerations" of the HRCQ survey shown in Table 1 will be employed to substantiate this hypothesis and gauge the perception towards the robot. Table 2 provides a nuanced analysis of correlations based on gender in the study, focusing on Perceived Usefulness, Perceived Safety and Trust, Perceived Ease of Use, and Ethical Considerations. The analysis will focus on examining the impacts on and the factors influencing the perceived abilities of the robot, aiming to understand the dynamics between user perceptions and robot capabilities.

4.1 Results related to Safety, Trust, and Usability

Regarding Perceived Safety and Trust, male participants exhibit a moderate positive correlation of 0.41 between the predictability of the robot's actions ("The robot's actions were predictable") and "It is acceptable for the robot to have much information about the user". This suggests that males are comfortable sharing information if the robot performs predictably. Similarly, the question "I felt safe using the robot" shows a moderate positive correlation of 0.45 with respect to "I should have full control of when and how the robot will assist me" for males, reinforcing the connection between perceived safety and the desire for more control. However, for female participants, a negative correlation was found between feeling safe and "I had to learn more about robots in order to be able to interact with the system," underscoring having more knowledge about the robot made it safer for them to interact with the robot.

Concerning Perceived Ease of Use, male participants demonstrated a moderate positive correlation of 0.41 between the questions "The robot met my expectations" and "It is acceptable for the robot to have much information about the user", indicating their comfort in sharing information when the robot delivers tasks as requested. Additionally, a moderate positive correlation of 0.43 is observed between it being acceptable for the robot to have much information about the user and the SUS score, suggesting that males are willing to share personal information as long as the system is felt to be more usable. For female participants, a strong negative correlation of -0.78 was found between "I found the robot easy to use" and "I am concerned about my privacy when using the robot." It means that as it was more easier for them to use the robot, they were less concerned about their privacy.

Pertaining to Perceived Interactions, male participants showed a moderate negative correlation of -0.43 for the question "I had to speak slowly to interact with the robot" and "It is acceptable for the robot to have much information about the user", suggesting that males felt it is not acceptable for the robot to have more information if they had to speak slowly. Similarly, female participants showed a strong positive correlation of 0.64 with respect to the questions, "I felt my voice volume was normal," and "I should have full control of when and how the robot will assist me.". This suggests that when they were confident about their voice volume, they expected full control of the robot.

4.2 Results related to Ethical Considerations

Relating to Ethical Considerations, a moderate positive correlation of 0.43 was observed among male participants between the

acceptance of a robot having extensive user information and both their System Usability Scale (SUS) scores and the robot meeting users' expectations and its actions being predictable, with these correlations noted at 0.41. This indicates that males are more willing to share information when they perceive the robot's actions as predictable and aligned with their expectations. Conversely, a moderate negative correlation of -0.43 exists between the need to speak slowly and the acceptance of the robot having extensive user information, suggesting that males are less receptive to the idea of the robot storing significant user data when they experience slower interactions. On the other hand, no statistically significant correlations are found among female participants regarding the acceptability of the robot possessing extensive user information. Male participants also exhibited a moderate positive correlation of 0.45 for the question, "I should have full control of when and how the robot will assist me" and "I felt safe using the robot". This suggests that males seek increased control when they feel secure. For female participants, we found a strong negative correlation of -0.78 between "I am concerned about my privacy when using the robot" and "I found the robot easy to use" and -0.58 for "I am concerned about my privacy when using the robot" and "I accomplished the given tasks rapidly." This suggests that female participants were more concerned about their privacy when the robot did not perform the tasks rapidly and if the robot was harder to use. The female participants also felt less safe interacting with the robot when they had to learn more about the robot. They also sought more control of the robot when they felt their voice was normal.

4.3 Discussion

Our study delved into the influence of gender diversity on participants' perceptions during interactions with robots, focusing on trust, safety, and privacy. We formulated hypotheses and used Kendall's Tau correlation analysis to uncover intriguing gender-specific insights. The key findings of our study are summarized below:

- **Acceptance of Robot Access to User Information:** Males showed a positive correlation between their willingness to share information with the robot and positive user experiences. This correlation was absent among females, suggesting potential differences in discretion and perceived benefits.
- **Desire for Control over Robot Action:** Males sought more control when feeling secure, while females desired control when their voice volume seemed normal, granting autonomy when it did not.
- **Privacy Concerns:** Males associated privacy concerns with robot errors, while females linked them to task speed and user-friendliness.

These findings emphasize gender's nuanced impact on human-robot interactions, informing inclusive robot design and development. Understanding diverse gender patterns becomes pivotal for creating more user-friendly robotics technologies as human-robot interaction evolves.

In summary, our study sheds light on the complex interplay between gender and human-robot interactions, offering valuable insights for researchers, developers, and designers in the field.

Table 2: Kendall's Tau significant Correlations for Hypothesis. The correlation (Corr) pertains to the table's respective row and column header. The correlation is separately calculated for the female and male participants. The correlation is considered statistically significant only if the p-value is less than 0.05, and all statistically significant correlations are presented in bold and underlined with dots (moderate correlation) or underlined with a line (strong correlation).

Metric/Survey Question	Metric/Survey Question	Corr: Male	Corr: Female
It is acceptable for the robot to have much information about the user.	The robot's actions were predictable.	**0.41** (p-value: 0.0306)	0.05 (p-value: 0.8385)
It is acceptable for the robot to have much information about the user.	The robot met my expectations.	**0.41** (p-value: 0.0338)	0.03 (p-value: 0.8894)
It is acceptable for the robot to have much information about the user.	SUS Score	**0.43** (p-value: 0.0144)	0.07 (p-value: 0.7493)
It is acceptable for the robot to have much information about the user.	I had to speak slowly to interact with the robot.	**-0.43** (p-value: 0.0202)	-0.21 (p-value: 0.3823)
I should have full control of when and how the robot will assist me.	I felt safe using the robot.	**0.45** (p-value: 0.0265)	0.45 (p-value: 0.0927)
I should have full control of when and how the robot will assist me.	I had to learn more about robots in order to be able to interact with the system.	0.05 (p-value: 0.7978)	**-0.66** (p-value: 0.0088)
I should have full control of when and how the robot will assist me.	I felt my voice volume was normal.	-0.15 (p-value: 0.4267)	**0.64** (p-value: 0.0099)
I am concerned about my privacy when using the robot.	All Robot Errors	**-0.48** (p-value: 0.0062)	0.09 (p-value: 0.7202)
I am concerned about my privacy when using the robot.	I accomplished the given tasks rapidly.	0.24 (p-value: 0.2053)	**-0.58** (p-value: 0.0286)
I am concerned about my privacy when using the robot.	I found the robot easy to use.	-0.03 (p-value: 0.8873)	**-0.78** (p-value: 0.0045)
I had to learn more about robots in order to be able to interact with the system.	I felt safe using the robot.	-0.18 (p-value: 0.3635)	**-0.58**(p-value: 0.0331)

5 CONCLUSION AND FUTURE WORK

In this research, we delved into the intricate dynamics of HRI, specifically exploring the impact of diverse genders on perceived trust, privacy, and safety. Rooted in our prior work on a collaborative cooking scenario with unstructured speech interactions [14], our previous research primarily focused on preferred interaction methods with structured and unstructured robots, without explicitly considering the influence of diverse genders.

Our investigation brought to light significant gender nuances: self-identified males exhibited heightened sensitivity to robot errors, while self-identified females prioritized data privacy concerns. Although cautious generalization is warranted, further research in this domain is crucial. These findings underscore the importance of tailoring robot design and deployment approaches to accommodate diverse user preferences.

As large language models, like ChatGPT [20], gain prevalence, transparent communication of intended data usage before collection becomes paramount. Beyond the identified correlations, numerous open-ended questions persist, necessitating additional data collection. These inquiries delve into the impact of personal idiosyncrasies and cross-cultural disparities linked to diverse genders, prompting further empirical exploration. Additionally, conducting rigorous studies on ethical and privacy considerations and their potential implications for HRI is imperative. Addressing these concerns enhances our understanding of HRI dynamics and contributes to the broader acceptance of robots in everyday contexts.

The nuanced gender-specific patterns uncovered and our original conclusion highlight the multifaceted nature of human-robot interactions and advocate for continued exploration and refinement in this evolving field. Addressing these concerns can foster broader acceptance of robots in everyday contexts.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant 2226165. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The authors would like to thank the participants of the user study for their feedback.

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