To The Effects of Anthropomorphic Cues on Human Perception of Non-Humanoid Robots: The Role of Gender*

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Abstract— **As non-humanoid robots increasingly permeate various sectors, understanding their design implications for human acceptance becomes paramount. Despite their ubiquity, studies on how to optimize their design for better human interaction are sparse. Our investigation, conducted through two comprehensive surveys, addresses this gap. The first survey delineated correlations between robot behavioral and physical attributes, perceived occupation suitability, and gender attributions, suggesting that both design and perceived gender significantly influence acceptance. Survey 2 delved into the effects of varying gender cues on robot designs and their consequent impacts on human-robot interactions. Our findings highlighted that distinct gender cues can bolster or impede interaction comfort.**

I. Introduction

In an era characterized by rapid technological evolution, robots are increasingly permeating diverse aspects of human life, transcending traditional roles in industrial settings to leave indelible marks on healthcare, search and rescue, environmental monitoring, and even social companionship [1].

Non-humanoid robots have demonstrated exceptional capabilities in specialized tasks, often surpassing what humanoid robots can achieve [2]. For instance, drones are indispensable for aerial mapping and surveillance, while creature-like robots can navigate rough terrains, showcasing potential applications ranging from geological surveys to agricultural practices [3]. Yet, these robots present unique challenges and opportunities in Human-Robot Interaction (HRI), making it crucial to explore how humans perceive and interact with these specialized entities [4].

Recent advancements in cognitive psychology suggest that humans are naturally inclined to anthropomorphize objects, attributing human characteristics to non-human entities [5]. This psychological tendency has significant implications for the design and deployment of non-humanoid robots, particularly in how they are gendered and subsequently perceived [6].

Our research targets an overlooked yet pivotal aspect of HRI: the attribution and perception of gender in non-humanoid robots. Despite extensive literature on humanoid robots, a glaring gap exists in understanding how gender plays a role in the design and interaction with non-humanoid robots [7]. We aim to fill this research void by scrutinizing how human perceptions, stereotypes, and expectations converge in shaping non-humanoid robot design and utility across diverse sectors [8].

One groundbreaking objective of this study is to explore the extent to which humans attribute gender to non-humanoid robots. Previous studies affirm that familiarity, including gender attributes, influences human comfort and robot interaction [9]. However, the inherent design of non-humanoid robots often lacks explicit human features, complicating the process of gender attribution [10].

Given this, we pose several research questions: How do varying degrees of gender cues in non-humanoid robots affect the dynamics of HRI? Could interactions be more effective, trustworthy, or relatable when specific gender cues are emphasized? Could such cues improve or impair task-specific performance, and how can this knowledge inform robot design [11]? We will conduct exhaustive surveys and experiments to probe these questions, contributing empirical data to a field dominated by theoretical discourse. Our methodological approach promises not only to deepen our understanding of HRI but also to direct future robot design and programming [12].

The real-world applicability of this research cannot be overstated. As robots increasingly share our workspaces, public spaces, and even homes, understanding the subtleties of human-robot interaction is crucial for societal acceptance and ethical considerations [13]. Our study aims to help evaluate non-humanoid robot design, challenging existing norms about gender and thereby cultivating more efficient human-robot collaborations [14].

II. Survey 1: Examination of Gender Attribution in Non-Humanoid Robots

This study aims to see how people view non-human-like robots, especially in terms of giving them human traits and gender characteristics. We want to know if people think of these robots as having human qualities and if they see them as male or female. Gender cues will be systematically manipulated utilizing visual and behavioral characteristics, including size, color, and design elements traditionally associated with masculinity or femininity.

Upon observation of each robot, participants will be required to articulate their perceptions of its gender, classifying it as either more masculine, more feminine, or gender neutral. We propose the following hypothesis:

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Hypothesis 1: Participants will tend to perceive the Spot robot as more masculine than the Mini-Cheetah.

Hypothesis 2: Gender attributions for the robots can be extrapolated from attribute ratings.

Hypothesis 3: There will be an inclination among participants to allocate more male-typed occupations to Spot while potentially designating some feminine-typed occupations to Mini-Cheetah.

A. Participants

A survey involving 150 participants comprised males (53.3%), and 70 females (46.7%). The participants were diverse in terms of race, with representation from Asian (10%), Middle Eastern (19.3%), European (32%), African (6.7%), and Latino (8%) backgrounds.

The participant's age range of 18 to 60 years, with means of 32 and SD= 4.53. Before the study, participants were asked about their fluency in English, as the survey questions were presented in English.

B. Survey Instrument

The study employed online methods to gather data on participants' perceptions of gender stereotypes in non-humanoid robots. For the online questionnaire, participants accessed a web-based form where they were provided with a video showcasing the Spot and Mini-Cheetah robots. The video included demonstrations of their capabilities, and participants were also shown photographs of the robots.

In addition to the online questionnaire, a subset of participants had the opportunity to interact with the Spot and Mini-Cheetah robots in person for a pilot study. These in-person sessions allowed participants to have hands-on experience with the robots and engage in direct interactions.

The study utilized different robot stimuli, including the Spot and Mini-Cheetah robots and a regular drone, the DJI model. The corresponding photos of these robots are displayed in Figure 1.

C. Pilot study

Before the main investigation, an initial pilot study was conducted at the University of Luxembourg. This preliminary study was conducted in person and involved participants within the age range of 25 to 55 years. During this preliminary survey, participants were asked to express the gender they attributed to each robot. The gender perception was measured on a scale from 1 to 5, where 1 signified a stronger feminine perception, 5 a stronger masculine perception, and 3 indicated a neutral perception. The primary objective of this pilot study was to determine whether it was feasible to gauge human perceptions of robot gender directly.

As anticipated, the Spot robot received a higher masculinity score with a mean of 3.72 (Standard Deviation, $SD = 08$), while the Mini-Cheetah robot was perceived as more feminine with a mean score of 3.08 ($SD = 17$).

Results show Individuals tend to assign gender to robots, even when the robots are non-humanoid. This tendency might suggest people seek similarities or familiar traits to the robots.

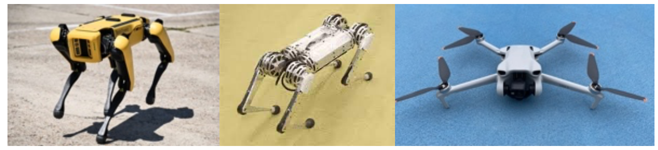

Figure 1 A selection of robotic stimuli used in Survey 1. From left to right: Spot, Mini-Cheetah, and DJI UAV

Furthermore, to ensure the appropriateness of our study's chosen attributes and occupations, we asked participants to rate each adjective based on its typical association with either males or females. The results indicated low standard deviations, suggesting a high degree of agreement among participants. In addition, the mean ratings of the participants generally aligned with societal norms and accepted gender stereotypes.

Furthermore, the results indicated that many participants were reluctant to respond directly to the question, often in a humorous or dismissive manner.

To mitigate this issue, we took inspiration from prior research by Eyssel et al. [15] and adopted an indirect approach to investigate how individuals attribute gender to non-humanoid robots, particularly non-creature-like robots like drones. Assigning gender directly to drones can be challenging for individuals to comprehend or envision.

D. Survey Detail

The initial question of the study prompted participants to assign a name to each robot. This provided insight into how participants perceived the robots, either as alive creatures, human-like entities, or mechanical objects. This approach to naming was inspired by [16], underscoring its efficacy in probing how individuals perceive and designate non-human entities.

To analyze the assigned names, we inspired from classification categories as outlined in [17]. The names were sorted into two primary groups: anthropomorphic and non-anthropomorphic. Within the anthropomorphic category, names were further subdivided into male, female, or both-gender-associated names. The non-anthropomorphic category features three subcategories: animal-kind, machine-kind, and things-kind. These subcategories were further dissected into male, female, and neutral classifications for both animal-kind and machine-kind.

The analysis entailed utilizing dictionaries and engaging five independent raters to evaluate the names. The evaluators rated each name, and the results were aggregated to determine common usage and associations. This systematic approach allowed for an unbiased and comprehensive understanding of the naming patterns. Furthermore, an examination was conducted to discern if any names bore biases shaped by media sources.

Then, participants rating specific attributes associated with non-humanoid robots. To accomplish this, we carefully selected 20 adjectives from existing studies [10], encompassing traits conventionally associated with male and female gender attributes. The chosen adjectives included ten behavioral characteristics and ten physical attributes. Participants were then asked to assign a rating to each adjective using a scale of 1 to 5. Table I lists the selected occupations for our study.

TABLE I THE PHYSICAL AND BEHAVIORAL ATTRIBUTES

Gender	Behavioral Attributes	Physical Attributes
Males	Assertive, Aggressive, Authoritative, Tough, Strong	Athletic, Heavy, Angular, Broad Shoulders, Rugged
Females	Empathetic, Delicate, Friendly, Sensitive, Compassionate	Graceful, Sleek, Slender, Elegant, Smooth

In continue, participants were asked to evaluate the suitability of 10 distinct occupations for the robots under consideration. The selection of occupations was based on the gender categories outlined in the framework proposed by Stroessner and Benitez [11]. Participants were instructed to assign a rating on a scale of 1 to 5 for each occupation. Higher values on the scale denoted a stronger perceived alignment between the robots and the given occupation. Table II gives the traditionally male and female occupations.

Furthermore, to comprehensively investigate participants' perceptions of the gender associations and biases related to non-humanoid robots, we implemented a ranking system for the selected occupations associated with each robot. Participants were instructed to assign a rank to each occupation. Occupation includes male-related, female-related, and traditional neutral occupations, including Security guard, health care assistant, and food server.

Finally, participants were directly asked to indicate their perception of the gender of the robots. They were instructed to provide a rating on a scale of 1 to 5, where 1 represented a perception of the robot as more feminine, 5 as more masculine, and 3 as gender-neutral. In addition to the gender perception questions, participants were also asked to provide personal information, including their age, race, and level of education.

E. Results

The Spot robot, characterized by more masculine attributes, was consistently perceived as more masculine by the participants ($M = 395$, $SD = 12$). Conversely, the Mini-Cheetah robot, with more feminine attributes, was perceived as more feminine than Spot but perceived more neutral ($M = 31$, $SD = 15$). The UAV received moderate gender perception scores ($M = 289$, $SD = 19$), neutral but more feminine also with high variance.

Results show that about Spot, most of the anthropomorphic names were male (68.1%), followed by gender-neutral (21.8%), and female (10.1%). On the other hand, in the non-anthropomorphic category, 27.9% were machine-kind names, 55.3% were animal-kind, and 17.8% were things-kind. In addition to the anthropomorphic and non-anthropomorphic classifications, an analysis was conducted to discern if the names bore influences from media sources. 34% of the names were found to be media-inspired, while media did not influence 66%.

For Mini-Cheetah, Neutral anthropomorphic names were the most frequent, comprising 30% of the 150. Male-associated names followed at 20%, and female-associated names at 15%.

Non-anthropomorphic names comprised 35% of the total, with machine-like, animal-like, and object-like contributing 10%, 15%, and 10%, respectively. 23 names (or 15% of the total names) were found to be inspired by media sources such as popular culture, movies, and literature.

Fig. 2 shows the mean score of the different attributes of robots. The results showed that Spot received significantly higher ratings for male attributes than female ones. Spot had a mean rating ($SD = 123$) for male attributes and a mean rating ($SD = 085$) for female attributes. Mini-Cheetah displayed male attributes, albeit at lower levels than Spot, but female attributes more than Spot. mean rating of ($SD = 161$) for male attributes and ($SD = 074$) for female attributes. The UAV received lower ratings for male ($SD = 044$) and female ($SD = 037$) attributes. The results are shown in Table III.

Spot, Mini Cheetah, and DJI UAV—in roles typically associated with male and female occupations. Spot scored the highest in male-dominated roles with a mean rating of 3.54, while Mini Cheetah led in female-dominated roles with a mean rating of 2.34. DJI UAV had the lowest mean ratings in both categories, at 1.834 for male and 1.154 for female roles. These findings suggest that Spot is perceived as more aligned with male attributes, while none of the robots significantly resonated with attributes commonly associated with female roles, indicating potential areas for further research in Human-Robot Interaction (HRI). The result is shown in Fig. 3 and Table III.

TABLE II TRADITIONALLY MALE AND FEMALE OCCUPATIONS

Gender	Occupation
Males	Police Officer, Firefighter, Construction Worker, Miner, Mechanics Assistance
Females	Nurse, Childcare, Housekeeper, Receptionist, Therapist

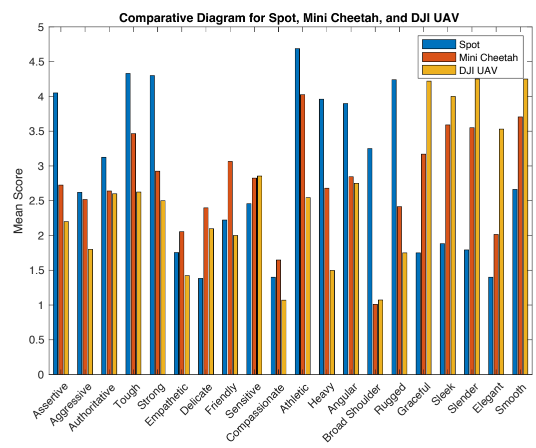

Figure 2 is a comparative attribute diagram regarding the Spot, Mini-cheetah, DJI UAV

TABLE III AVERAGE SCALE FOR DIFFERENT ATTRIBUTES FOR SPOT, MINI-CHEETAH, DJI UAV

	Spot	Mini Cheetah	DJI UAV
Female Behavior	1.8435	2.398	1.8892
Male Behavior	3.685	2.8545	2.345
Female Physical	1.8976	3.206	4.05
Male Physical	4.007	2.595	1.923

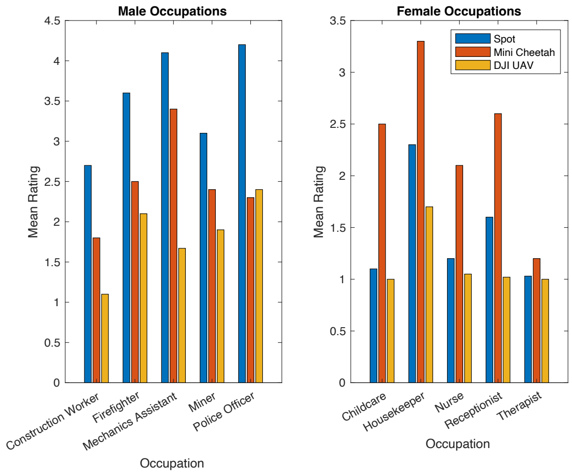

Figure 3 Average suitability ratings for Spot, Mini-cheetah, and DJI UAV in diffrent traditionally male and female occupations.

Furthermore, the participant's perceptions of the robots' gender attributes influenced their evaluations of their suitability for different occupations. The association between the behavioral and physical attributes of the robots and specific job roles indicates that humans expect congruence between robot attributes and job requirements. This finding highlights the importance of developing robots with appropriate attributes and capabilities to enhance their acceptance and effectiveness in specific occupational contexts. The results are given in Table IV.

In this survey phase, we employed a ranking system for occupations to explore participants' gendered perceptions of non-humanoid robots, Spot and Mini Cheetah. Spot was predominantly ranked higher for traditionally considered male-dominated roles, like a security guard, while Mini Cheetah led in healthcare assistance, a role generally associated with female attributes. Fig. 4 demonstrates the ranking score of each robot for different occupations.

III. SURVEY 2: EXAMINATION OF DIFFERENT LEVELS OF GENDER CUES ON NON-HUMANOID ROBOTS

This survey examines the impact of gender cues and anthropomorphism in non-humanoid robots on HRI Specifically, the survey aims to understand how the attribution of gender-related attributes and human-like qualities to non-humanoid robots, influences various aspects of HRI, including perceived efficiency in task performance, teammate selection, perception of robot gender, comfort level with the robot, politeness in interaction, and human expectations in HRI. The hypotheses are as follows.

Hypothesis 1: Attributing gender-related attributes to non-humanoid robots significantly influences participants' perceptions of their task efficiency and their likelihood of choosing the robot as a teammate over a human.

TABLE IV COMPARATIVE MEAN SUITABILITY RATINGS OF ROBOTS FOR AGGREGATED TRADITIONALLY MALE AND FEMALE OCCUPATIONS.

Robot	Male Occupations	Female Occupations
Spot	3.54	1.446
Mini Cheetah	2.48	2.34
DJI UAV	1.834	1.154

Hypothesis 2: The level of anthropomorphism in non-humanoid robots influences participants' perception of the robots' gender and their comfort level with the robot.

Hypothesis 3: The degree of gender symbolism in non-humanoid robots significantly affects participants' politeness in their interactions with the robots.

Hypothesis 4: The presence of anthropomorphic gender cues in non-humanoid robots significantly affects participants' expectations and preferences in human-robot interaction.

A. Participants

We surveyed 120 University of Luxembourg participants aged 20-55 years. Among the participants, 56% identified as male and 44% as female, with a mean age of 32 and a standard deviation of 10.32. Given the diverse composition of the university's student body, the participants represented various racial backgrounds, including Asian (10%), Middle Eastern (27%), European (48%), Black or African American (5%), and Latino (6%). Regarding educational qualifications, we inquired about the participants' levels of education, revealing that 73% were either Ph.D. students or held higher degrees, 20% held master's degrees, and the remaining participants fell into other categories.

B. Survey Instrument

In this survey, participants were randomly assigned to one of the four categories we designed. Upon accessing the survey, participants were presented with three images related to the topic and watched a 20-second video featuring a robot introducing itself. Following this, participants were directed to complete the survey, which typically took approximately 5 minutes.

In this study, we utilized AI technology, to modify the design of Spot. We instructed the model to generate diverse versions of Spot, including more feminine, masculine, machinelike designs and a dog-shaped variant. In this survey, participants were randomly separated into four categories. Fig. 5 show the different design of the spot.

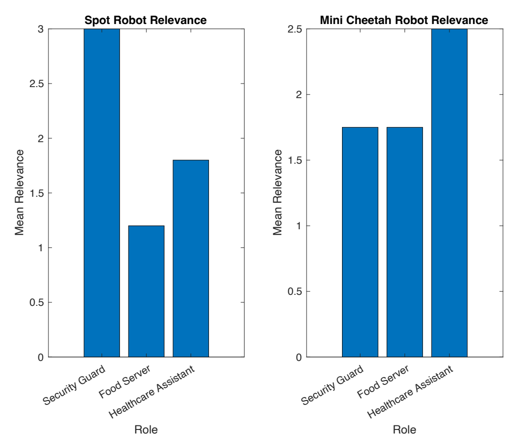

Figure 4 Average ranking score for traditionally male, neutral, and female occupation.

Figure 5 Different designs of Spot generating by the different AI tools

For each variant, a 20-second video was produced, wherein Spot introduced itself. The dialog used across all designs was, "I am Spot. I can assist you in various applications and possess numerous capabilities." The masculine design utilized a male voice, the feminine design employed a female voice, the dog-like design conveyed its message through barking accompanied by subtitles, and the machine-like design featured a neutral voice. All voiceovers were generated using Siri.

C. *Pilot Study*

A preliminary study was conducted with a sample of 20 participants. The participants were asked to rate the perceived gender of various voice samples, and Spot robot designs on a 5-point Likert scale, where 1 represented a more feminine perception and 5 a more masculine perception.

The neutral voice sample was perceived as slightly more feminine, with a mean rating of ($M = 33$, $SD = 13$). The male voice sample sounds masculine ($M = 45, SD = 07$), and the female voice sample sounds feminine ($M = 14$, $SD = 05$)

Regarding Spot designs, the masculine design was perceived as the most masculine ($M = 45$, $SD = 04$), followed by the machine-like design ($M = 39, SD = 14$). The feminine design was perceived as less masculine ($M = 26, SD = 15$), and the dog-shaped design received ($M = 32$, $SD = 08$). These findings ensure its validity in examining gender attributions and anthropomorphic tendencies in non-humanoid robots.

D. *Survey Detail*

To assess participants' perceptions of Spot's efficiency in performing various tasks, we asked them to evaluate the likelihood that Spot could complete specific jobs. We presented participants with 10 occupations listed in Table V. Participants were instructed to rank each job on a scale from 1 to 5, with 1 indicating low likelihood and 5 indicating high likelihood of Spot's success in that task.

TABLE V OCCUPATION.

Category	Occupations
Traditionally Female	Nurse, Childcare Worker, Housekeeper, Flight Attendant
Traditionally Male	Construction Worker, Firefighter, Mechanic, Security Guard
Gender-Neutral	Librarian, Food Server

In addition, to investigate the influence of gender cues on the selection of a robot as a teammate, we designed a scenario in which participants had to choose between a gendered humanoid robot teammate and Spot for a competition to examine whether the presence of anthropomorphic gender cues in non-humanoid robots affects participants' expectations and preferences in HRI ask participant to assign a 1-5 to the robot, how they perceived the robot's gender.

Furthermore, to assess the impact of gender cues on participants' comfort level with the Spot robot, we asked participants to rate their comfortability in being around the robot for an extended period on a scale from 1 to 5.

Finally, we aimed to investigate whether different levels of gender cues in non-humanoid robots can influence participants' behavior towards the robots, specifically focusing on politeness. Participants were asked to rate their likelihood of exhibiting aggressive behavior towards the Spot robot if it made a mistake on a scale from 1 to 5.

E. *Results*

A one-way ANOVA revealed a significant effect of gender cues on perceived efficiency in task performance $[F(3\,116) = 732,\ p = 0001]$. Post hoc comparisons indicated that the Masculine Spot design, with an average suitability score of 3.22, was perceived as the most appropriate across all occupations. Conversely, the Machine-like Spot, with the lowest overall average, was deemed the least preferred for general occupations. Fig. 6 and Fig. 7 demonstrate the average suitability score for each design for different occupations.

Participants preferred the Masculine Spot design for the traditionally male scenario, reflecting the perception of masculine robots as more adept in challenging terrains. In the traditional female scenario, the Feminine Spot design was slightly favored, reflecting societal norms associating caregiving roles with femininity. However, male and female humanoid robots received higher scores, suggesting a preference for humanoid assistance in medical contexts. In the culinary competition, societal biases linking cooking roles with femininity influenced preferences towards the Feminine Spot design and the Humanoid Female Robot. The average score for corresponding result is shown in the Fig. 8.

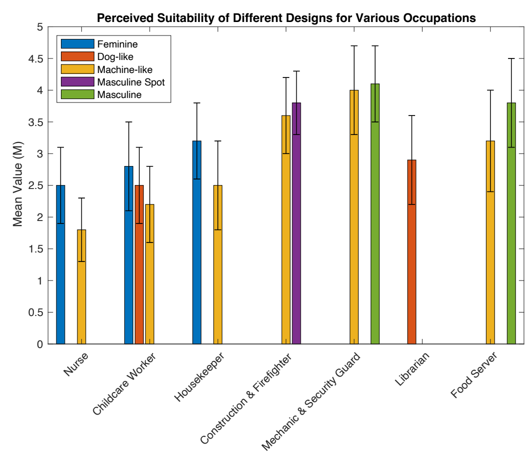

Figure 6 Mean scaling of the perceived suitability of different designs of Spot for different occupation.

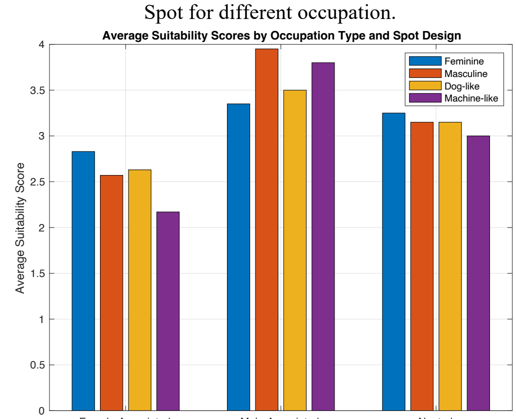

Figure 7 average suitability score regarding different designs of Spot for different occupations.

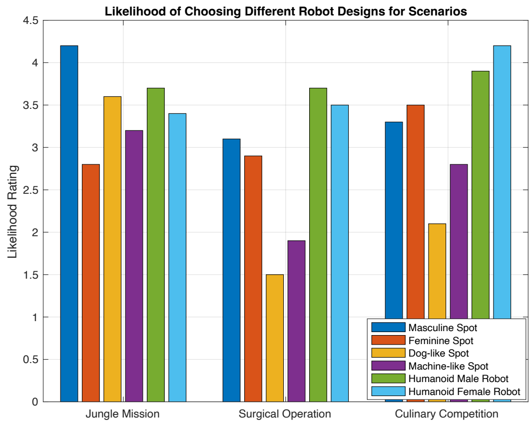

Figure 8 Mean likelihood of choosing the different design of the spot for traditionally male-female and neutral scenarios

There was a significant effect of gender cues on the perception of gender at the $p < 005$ level for the four conditions $[F(3\,116) = 914\,p < 001]$. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the masculine Spot ($M = 46$, $SD = 06$) was significantly different from the feminine Spot ($M = 402$, $SD = 13$), the machine-like Spot ($M = 337$, $SD = 154$), and the dog-like Spot ($M = 37$, $SD = 09$) and seems more masculine than feminine.

There was a significant effect of gender cues on comfort level at the $p < 005$ level for the four conditions $[F(3\,116) = 685\,p = 002]$. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the feminine Spot ($M = 43$, $SD = 05$) was significantly different than the masculine Spot ($M = 39$, $SD = 08$), the machine-like Spot ($M = 28$, $SD = 09$), and the dog-like Spot ($M = 29$, $SD = 10$).

There was a significant effect of gender cues on politeness at the $p < 005$ level for the four conditions $[F(3\,116) = 432\,p = 006]$. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the feminine Spot ($M = 23$, $SD = 08$) was significantly different from the masculine Spot ($M = 27$, $SD = 09$), the machine-like Spot ($M = 32$, $SD = 10$), and the dog-like Spot ($M = 37$, $SD = 11$).

IV. Discussion and Conclusion

Surveys 1 and 2 consistently found that gender symbols in robots significantly influenced participants' perceptions and behaviors. Survey 1 found that people tend to anthropomorphize robots and attribute human-like emotions and intentions to them. Also, people tend to perceive non-humanoid robots as more masculine.

This study addressed the gender perception of non-humanoid robots and revealed the tendency of humans to attribute human characteristics to them. For example, the Spot robot is seen as primarily masculine, a view likely influenced by its design and behaviors reminiscent of masculine characteristics. In contrast, the mini cheetah was considered more neutral and less masculine than the spot. Naming patterns further reinforced these perceptions, with Spot often giving them masculine names. Significantly, the media influenced 34% of Spot names, indicating outsider bias. This emphasizes the central role of media in shaping perceptions and potentially enhancing human-robot interaction (HRI).

In addition, this research showed the relationship between the appearance and behavior of the robot and their suitability for specific jobs. It also showed that people tend to have a connection between the features of robots and the role attached to them.

Quantifying these attributes can offer more insights into how robots are perceived and can guide their design to align with specific societal roles or expectations. Furthermore, an intriguing observation from Survey 1 was the inclination of participants to assign animal names to robots. This suggests a strong association with physical attributes, reiterating the significance of design parameters. It becomes evident that design elements are not mere aesthetics; they profoundly influence HRI. Survey 2 expanded on this by introducing different levels of anthropomorphism, ranging from the machine-like Spot to a dog-like variant. The findings indicated that the extent of anthropomorphism notably affected participants' comfort levels, gender perceptions, and teammate preferences and exceptions for assigning an occupation.

Regarding assigning occupations, people generally believe non-humanoid robots are more suitable for neutral and masculine occupations than feminine ones. Moreover, assigning masculine attributes to non-humanoid robots seems more intuitive, suggesting people can more readily identify these attributes in such robots. While the machine-like robot was deemed an ideal teammate for tasks, the feminine and masculine versions evoked more distinct gendered perceptions due to their pronounced anthropomorphic designs This indicates that when robots display certain human-like traits, people are more prone to applying gender stereotypes to them. For instance, in Survey 2, the masculine Spot was perceived as more efficient in task performance than its feminine counterpart. This aligns with traditional gender roles in which men are often linked with mechanical and technical tasks.

Additionally, the masculine Spot was preferred over the feminine Spot as a teammate, hinting at a potential bias where masculine traits are associated with competence in specific tasks. However, regarding comfort levels, Survey 2 revealed a twist: Participants felt more at ease with the feminine Spot than with its masculine or machine-like versions. This might be due to societal views associating feminine traits with warmth, friendliness, and approachability. Such results mirror the broader societal stereotypes and biases that frequently link femininity with nurturing roles and masculinity with technical competence.

A fascinating insight from Survey 2 was the role of gender cues in shaping politeness. Participants were least aggressive towards the feminine Spot when it erred, potentially mirroring societal norms that advocate for gentler interactions with females. Conversely, the machine-like or dog-like Spot designs elicited reduced politeness, suggesting that human interactions become less empathetic and courteous as a robot moves away from human-like features (either towards machinery or animals). According to the results, a robot whose design aligns with its intended purpose will likely be accepted and trusted by humans, especially in tasks requiring close cooperation between humans and robots.

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