Gender and Security Robot Interactions: A Brief Review and Critique

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Abstract

Although security robots are being deployed to enforce laws in both private and public spaces, there is a growing concern that the public may be not willing to accept them. Recently, several papers have suggested that both the human gender and the robot's perceived gender can help determine whether security robots will be accepted. To better understand whether there is a relationship between gender and human interactions with security robots, the researchers for this paper conducted a literature review. Overall, the review found mixed support for the assertion that gender matters in human interactions with security robots. This paper also provides an important reflection point for discussion and future research.

Keywords

Gender, Gendering robot, Human–Robot Acceptance, Human–Robot Interaction, Security Robots

Introduction

Recent literature suggests that gender may undermine the widespread acceptance of security robots (Marcu et al., 2023). This paper defines security robots as robots used to perform any security task. Security robots are a cost-effective solution for law enforcement in various environments, including streets, malls, and hazardous areas (Bordbar et al., 2022; Knightscope, 2023; Mays, 2023; McGuire, 2021). The growing deployment of security robots, projected to reach a global market value of $3.68 billion by 2026 (Statistics Market Research Consulting, 2019), underscores the importance of comprehending their acceptance (Marcu et al., 2023; McGuire, 2021). However, recent studies suggest that both the gender of humans and the gendering of robots are critical factors in this understanding (Tay et al., 2014; Weßel et al., 2022). Gender significantly influences human-robot interactions (Seaborn and Pennefather, 2022a) and is intertwined with social, economic, and political inequalities in societies (Acker, 2006; Alcoff, 2005; Fortunati and Edwards, 2022), shaping individuals' identities (DiTomaso et al., 2007; Howard, 2000) and lived experiences (Chattopadhyay et al., 2008; Chattopadhyay et al., 2004).

Despite its importance, there is a lack of systematic understanding of the role of gender in human–security robot interactions. Consequently, there is a need to reflect on our understanding and identify limitations and opportunities for further research in this area. To do that, we conducted a literature review to assess and understand the state of knowledge in the study of gender in human–security robot interactions. We asked the following research questions: Does the existing literature support the assertion that the gender of a security robot and/or human impacts interactions with security robots? If not, what is needed in the future of development to answer this question?

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This paper examines 11 studies encompassing 2047 participants, providing several contributions to the literature. First, the review found mixed support for the assertion that gender can help us determine whether security robots will be accepted. Second, significant results suggest (a) a preference for male-gendered security robots, and (b) a higher preference among self-reported women than self-reported men for security robots. Finally, this paper highlights limitations and future research opportunities to advance the understanding of gender in security robot interactions.

Theoretical Background

Stereotyping has been identified as an important factor in understanding the role of gender in human–robot interaction (Weßel et al. 2022). Stereotyping can be defined as the beliefs and expectations associated with the characteristics and attributes of members of a particular group that can lead to general expectations about the behavior of individuals in that group (Dovidio et al. 2010; Ellemers 2018). These expectations can be implicit, yet persistent and stable over time (Ellemers 2018). Even when individuals behave in ways that are inconsistent with their stereotypes, others may focus on behaviors that reinforce these stereotypes (Dovidio et al. 2010). Additionally, stereotyping can lead individuals to engage in behaviors that align with or reinforce stereotypical views of their group (Ellemers 2018).

Stereotyping can explain the importance of gendering robots, especially security robots (Weßel et al. 2022). Humans may import their general expectations about appropriate gender roles from humans to robots, leading to certain expectations and biases about robot gender in specific tasks or contexts (Fortunati and Edwards 2022; Weßel et al. 2022). For instance, research has shown that a male-gendered robot may be perceived as more suitable for technical tasks, while a female-gendered robot may be viewed as more appropriate for household and care services (Bernotat et al. 2021; Eyssel and Hegel 2012).

Police abuse of power including unlawful arrest, misuse of authority, and sexual harassment and intimidation by law enforcement personnel has been a growing concern throughout many societies (Cao and Huang 2000; Radford 1987). Social activists have highlighted the potential problems associated with the use of physical force in policing (Shjarback and White 2016). Women, among other groups, have been particularly subject to the abuse of power by law enforcement officers. A recent case in the United Kingdom highlighted the horrific police violence against women (Lowerson 2022; Rainbow 2021). In contrast, integrating security robots is seen as a safe and secure alternative. Research shows that people, especially women, feel safer and have fewer concerns about the potential for sexual harassment and violence when interacting with robots (Gallimore et al. 2019; Tay et al. 2014; Tay et al. 2013).

Against this backdrop, gender's potential significance for security robot acceptance suggests substantial consequences for their development and deployment. As security robots become more prevalent, it becomes imperative to understand gender implications in the context of security robots.

Method

We conducted a literature review using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement as a guide to identifying relevant research on the impact of gender on the acceptance of security robots. PRISMA is a widely adopted set of guidelines for literature reviews that ensures structured and transparent reporting (Page et al. 2021). The process is depicted in Figure 1.

Search Process

We systematically searched Google Scholar, ACM Digital Library, IEEE Xplore, and Scopus using specific keywords to find relevant studies. We used a set of search terms for keywords: (Security OR Peacekeeping OR Guard OR Police OR Military OR Safety OR Patrol OR Protection) AND (Robot OR Robots). This decision was made because we found that the terminology for security robots used in different pieces of literature is inconsistent. For example, some researchers use terms such as "guard robot" and "police robot." Therefore, we broadened the singular term "security robot" to encompass additional keywords related to the functions and uses of security robots. This search yielded 4449 results. During the cross-referencing procedure, we identified and included one more paper that met our criteria. Finally, the database was narrowed to 4116 studies after duplicates were removed.

Screening Procedure

We conducted a thorough screening using predetermined criteria: studies published as academic works in English; studies involving human participants in user studies; studies measuring or using security robots; and studies discussing or manipulating the impact of either human gender or security robots' gender. The screening process began with a review of titles and abstracts. This yielded 544 studies that met the inclusion criteria. After a full-text review, we excluded 533 papers. Eleven papers met all inclusion criteria and were included in the final analysis. The screening process was conducted manually and managed with the Rayyan application (Ouzzani et al. 2016).

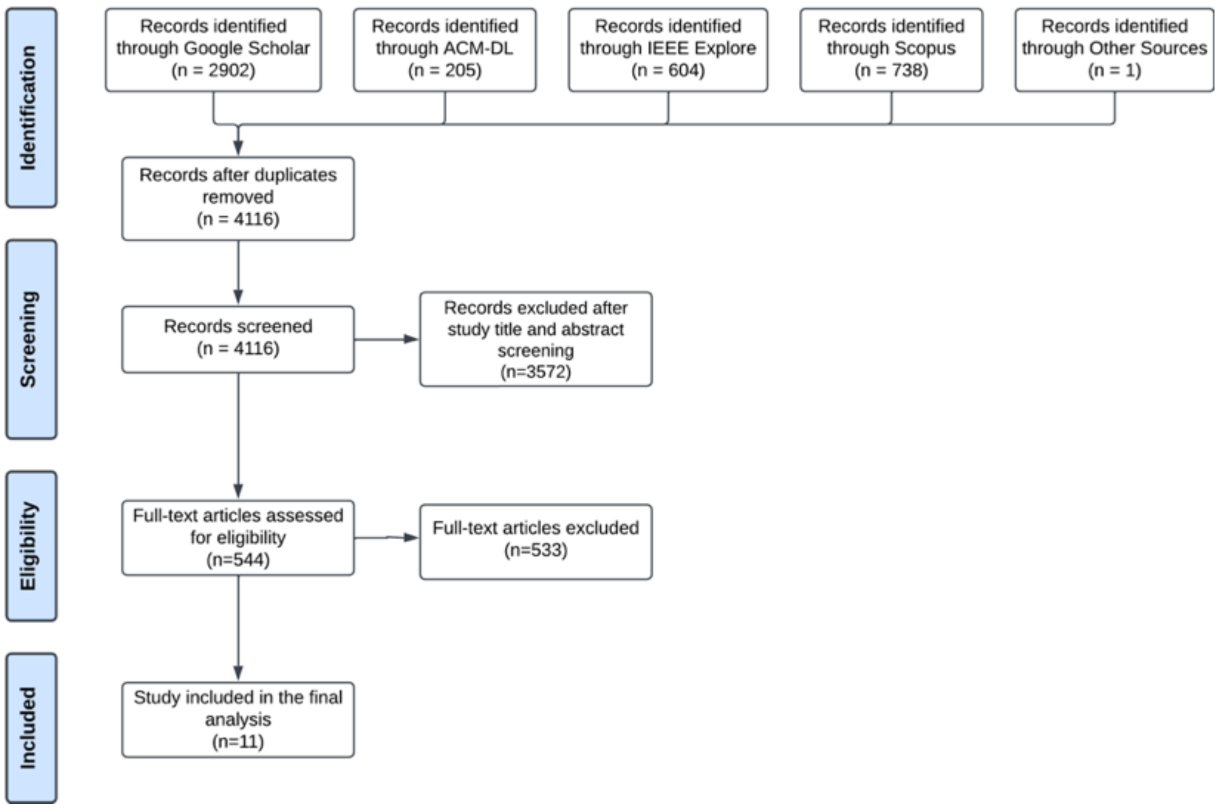

Figure 1. Prisma Flow Diagram of Literature Review Process

Results

Outlets

Of the 11 included studies, an equal number were published in journals and conferences. Specifically, five were published in journals while five were published as conference proceedings. The remaining study was a thesis paper. The journal publications included two in *IEEE Transactions on Human-Machine Systems* and one each in *Frontiers in Psychology*, *Computers in Human Behavior*, and the *International Journal of Social Robotics*. The conference proceedings were published in the *ACM Conference on Human-Computer Interaction*, the *International Conference on Engineering Psychology and Cognitive Ergonomics*, the *International Conference on Cross-Cultural Design*, the *Human Factors and Ergonomics Society Annual Meeting*, and the *Conference on Human Factors in Computing Systems*.

Sample

Across the studies reviewed, the total sample size was 2047, with a mean value of 186 and a standard deviation of 146. The largest sample size was 531 participants (Inbar and Meyer 2019), while the smallest was 17 (Inbar and Meyer 2015). However, after excluding these outliers, the mean sample size was 167 with a standard deviation of 89. This suggests that the studies overall had a relatively large sample size.

The average participant age was 32 years (± 8 SD). Additionally, only two studies (Bryant et al. 2020; Rogers et al. 2020) reported the racial distribution of participants. In these studies, 80% of participants identified as White, 4.67% as Hispanic or Latino, 8% as Black or African-American, and 6.67% as Asian. Five studies (Bryant et al. 2020; Enz et al. 2011; Matthews et al. 2020; Rogers et al. 2020; Wang 2014) reported the education level of participants, with most participants reporting they had a college degree.

Among the 11 studies reviewed, 10 reported the gender distribution of their participants. In all but two studies (Gallimore et al. 2019; Wang 2014), the distribution was relatively even. However, in Gallimore et al. and Wang's studies, there was a higher percentage of male participants than females. Overall, men represented 54.3% of the total sample while women comprised 45.7% of the total sample size.

Tasks

The studies included in this review utilized various methods to explore gender and gendering in human–security robot interaction. The most common method of interaction with the security robot was through the use of videos and text in the questionnaire. Bryant et al. (2020), Gallimore et al. (2019), and Rogers et al. (2020) all employed pre-recorded videos to depict interactions between participants and the robot, with Bryant et al. and Rogers et al. manipulating the voice and name of the robot to convey gender. Matthews et al. (2020), Enz et al. (2011), and Wang (2014) all utilized text-based scenarios presented in an online questionnaire to understand participants' acceptance of security robots. Inbar and Meyer (2019) used a combination of text, pictures, and animation to illustrate male and female interactions with the security robot, while Inbar and Meyer (2015) used a printed booklet with scenarios. Tay et al. (2014) and Tay et al. (2013) were the only studies to conduct experiments in a physical laboratory setting, where they manipulated the gender of the robot by using male and female voices and names.

In all studies except for Yueh and Lin (2016), participants were presented with scenarios of human–security robot interaction to test hypotheses. Access control tasks were used in three studies (Gallimore et al. 2019; Inbar and Meyer 2015; Inbar and Meyer 2019); these tasks required the robot to check the participant's identification to grant or deny access to a particular area. The studies presented the interaction through either videos or text. Integrated security tasks were the second most popular task, used by Tay et al. (2014) and Tay et al. (2013); these tasks included surveillance, detecting intrusions, and reminding participants of potential emergencies to study human–robot interactions. The remaining studies used robot introductions (Bryant et al. 2020; Rogers et al. 2020) or scenario-based descriptions (Enz et al. 2011; Matthews et al. 2020; Wang 2014) to explore the impact of gender in human–security robot interaction.

Outcomes

The impact of user gender and robot gendering was assessed through two outcomes: perceptions of the robot and robot acceptance. Perceptions of the robot refer to participants' image and evaluation of the robot, including their perceptions of the threat/risk created by the robot's behavior and functionality, and its correctness in operation (Inbar and Meyer 2015; Inbar and Meyer 2019; Wang 2014). Additionally, perceptions of the masculinity/femininity of the robot, its extroversion, and its cognitive evaluations were assessed (Tay et al. 2014). Participants' affective attitudes/evaluations and perceived behavioral control toward the robot were also measured (Enz et al. 2011; Matthews et al. 2020; Tay et al. 2014).

Robot acceptance was a common outcome and was measured through various indicators, such as trustworthiness (Gallimore et al. 2019), trust (Tay et al. 2014), reliance intention (Bryant et al. 2020; Gallimore et al. 2019; Rogers et al. 2020), intention to use (Gallimore et al. 2019; Rogers et al. 2020; Tay et al. 2013; Yueh and Lin 2016), support of development (Wang 2014), preference (Rogers et al. 2020; Tay et al. 2014; Tay et al. 2013), and expectations (Enz et al. 2011).

Findings

We investigated the impact of gender on human–security robot interaction. Our findings are categorized into two research thrust areas: the impact of human gender and the impact of robot gender.

Gender of the Human in Human–Security Robot Interaction

Eight studies examined the influence of participant gender on robot perceptions and acceptance (Table 1).

Perceptions of Robots: As presented in Table 1, five studies investigated the impact of human gender on perceptions of security robots, and the results were mixed. The results from four of the five studies are not statistically significant, indicating that the gender of the human did not impact perceptions of robots. Inbar and Meyer (2015) and Inbar and Meyer (2019) utilized text, pictures, and animations in an online survey to investigate the impact of human age (young/old), gender (male/female), and politeness on participants' evaluations of robot behavior. They did not find any significant effect of robot gender on the perceived threat, perceived fairness, perceived functionality, or perceived appropriateness of the robot. Matthews et al. (2020) used descriptions in an online questionnaire to investigate the effect of gender on attitudes toward general robots, as well as mental models of autonomy toward security robots. Their findings indicated that women hold a significantly more negative attitude toward general robots than men. However, the study did not report any direct results on the effect of human gender on security robots. Enz et al. (2011) utilized a survey to study the impact of human gender on people's affective evaluations of robots. They provided text to describe scenarios for eight future roles of robots in society and found no significant differences in people's evaluations of security robots between female and male participants. Finally, Wang (2014) is the only study that found a significant impact of human gender on perceptions of a robot. Wang used descriptions in an online survey to understand how gender influences perceptions toward robots used in various societal contexts. The results indicated that female participants perceived adopting domestic robots (for personal security and housework) as more risky than male participants did.

Robot Acceptance: Five studies investigated the impact of human gender on the acceptance of security robots through variables such as trust, trustworthiness, expectations, and intention to use. The results were mixed. Bryant et al. (2020) conducted an online survey to investigate whether the gender match between the participant and the robot impacted the user's perceived occupational competency and trust. The results showed that the gender of participants did not significantly impact their perception of the robot's occupational competency or trust in its occupational competency. Enz et al. (2011) investigated the impact of participants' gender on their expectations about the timeframe for security robots and related scenarios to become a reality in the future. Their results showed no significant differences in the expectations of male and female participants. In another study, Gallimore et al. (2019) explored the gender effects on trust in an autonomous security robot. They found that women were more trusting of the robot and rated the robot higher in ability and benevolence than men did. Women also demonstrated a higher desire than men to use robots in hospital and campus contexts. However, there was no significant difference between men and women regarding perceptions of the integrity or the use of robots in military/public settings. Yueh and Lin (2016) conducted a survey to investigate attitudes and expectations toward intelligent home service robots. They asked participants about their requirements for services provided by the robots and found that women emphasized the services of security and safety more than men did. Finally, Wang (2014) examined the impact of human gender on acceptance of robots used in various societal contexts. One of the six contexts they examined was domestic robots, which they described as robots responsible for both housework and personal security tasks. Participants rated their acceptance of this robot, and the results revealed that men were more supportive of developing such domestic robots than women were.

High-Level Outcomes	**Low-Level Outcomes**	**Study**	**Results**	**Results General**
Perceptions of Robots	Perceived Threat	Inbar and Meyer 2015, Inbar and Meyer 2019	N.S.	Mixed
	Perceived Fairness		N.S.	
	Perceived Functionality		N.S.	
	Perceived Appropriateness		N.S.	
	Perceived Risk	Wang 2014	Sig	
	Mental Model of Autonomy	Matthews et al. 2020	NR.[b]	
	Affective Evaluations	Enz et al. 2011	N.S.	
	Trust	Bryant et al. 2020	N.S.	Mixed

Robot Acceptance			Gallimore et al. 2019	Sig	
	Ability		Bryant et al. 2020	N.S.	Mixed
			Gallimore et al. 2019	Sig	
	Benevolence		Gallimore et al. 2019	Sig	
	Integrity		Gallimore et al. 2019	N.S.	
	Intention to Use	Public, Military	Gallimore et al. 2019	N.S.	Mixed
		Hospital, Campus	Gallimore et al. 2019	Sig	
		Home	Yueh and Lin 2016	Sig	
	Expectations		Enz et al. 2011	N.S.	N.S.
	Support of Development		Wang 2014	Sig[a]	Sig

[a] Men rated the outcome higher than women for this item. For all other significant effects listed in Table 1, women rated the outcome scores higher than men.

[b]Not reported.

Table 1. The Impact of Human Gender

Robot Gender in Human–Security Robot Interaction

Four studies examined how robot gender influences perceptions of robots and their acceptance (Table 2).

Perceptions of Robots: Tay et al. (2014) is the only study to examine the effect of robot gender on perceptions of robots. They conducted a lab experiment to examine the effect of social stereotypes (gender and personality) and found that participants had more positive evaluations, attitudes, perceived behavioral control, and subjective norms toward the male security robot as compared to the female robot.

Robot Acceptance: Four studies investigated robot acceptance and found some consistent results: robot gender significantly influences intention to use. However, no significant differences were found regarding other low-level outcomes. Tay et al. (2014) and Tay et al. (2013) both examined participants' intention to use and found that male-gendered security robots were perceived to be more useful and had a higher user intention rating as compared to female-gendered security robots. The authors also found slightly higher ratings of perceived ease of use for male-gendered robots as compared to female-gendered robots. However, there was no significant effect of robot gender on perceived trust. Bryant et al. (2020) conducted an online survey to examine the impact of robot gender on perceived robot occupational competency and perceived trust in the robot's occupational competency. Their findings indicated that robot gender did not affect the outcome variables. Similarly, Rogers et al. (2020) investigated the influence of robot gender on occupational competency, trust in occupation, and preference for the robot over a human male/female. They concluded that robot gender did not affect these variables.

High-Level Outcomes	**Low-Level Outcomes**	**Study**	**Results**	**Results General**
Perceptions of Robots	Affective Evaluations	Tay et al. 2014	Sig	Sig
	Cognitive Evaluations		Sig[b]	
	Perceived Behavioral Control		Sig[b]	
	Positive Attitude		Sig[b]	
	Subjective Norms		Sig	
Robot Acceptance	Trust	Tay et al. 2014, Rogers et al. 2020, Bryant et al. 2020	N.S.	N.S.
	Occupational Competency	Rogers et al. 2020, Bryant et al. 2020	N.S.	N.S.

	Preference of Robot over Human	Rogers et al. 2020	N.S.	N.S.
	Intention to Use	Tay et al. 2013, Tay et al. 2014	Sig	Sig

[a]All significant effects in Table 2 are the outcome score of male robots higher than female ones.

[b]Marginally significant effect.

Table 2. The Impact of Robot Gender

Gender Match Between Humans and Robots

Last, we looked at whether a match between human gender and robot gender influenced the acceptance of security robots. Among the 11 papers reviewed, only Bryant et al. (2020) investigated the combined effect of human and robot gender. The researchers explored whether participants' perceived trust in the robot's occupational competency would increase when the robot's gender matched the participant's gender. Contrary to their hypothesis, no significant results emerged, indicating that the gender match between humans and robots does not impact the acceptance of security robots.

Discussion

Overall, the review found mixed support for the assertion that gender can help us understand the acceptance of security robots. Nonetheless, the significant results all seem to go in the same direction, indicating a general preference for what the studies termed "male security robots" (Tay et al. 2014; Tay et al. 2013). In addition, participants who self-reported as women showed a greater preference for security robots than those who self-reported as men did (Gallimore et al. 2019; Yueh and Lin 2016). Next, we discuss the study's contributions, limitations, and opportunities for future work.

Preference for Male-Gendered Security Robots

Stereotyping might imply a preference for a male security robot over a female security robot. The literature does not provide a clear and consistent view that supports this assertion. But when significant differences were found, they indicated a preference for male security robots over female ones. There was no evidence of preference for what the studies labeled female security robots over their male-robot counterparts. That being said, the two studies that found significant results appear to be related and may represent a single study (Tay et al. 2014; Tay et al. 2013), as do the two studies that did not find significant differences (Bryant et al. 2020; Rogers et al. 2020). In all, more work is needed to fully assess the stereotyping of gender and its impact on security robot acceptance.

Women's Preference for Security Robots

Scholars suggest that women may be more accepting of security robots than men (Tay et al. 2014). However, the existing literature does not support this claim. Nonetheless, when significant differences were found, two papers indicated a higher women's preference for security robots (Gallimore et al. 2019; Yueh and Lin 2016). Although Wang (2014) is the only study with contrary findings, it did not measure attitudes toward security robots specifically but a general attitude toward domestic robots which could perform house and personal security work. Future studies should carefully consider the influence of specific usage scenarios and separate them. Gallimore et al. (2019) provide additional insights, suggesting that women prefer security robots more than men in hospitals and campus contexts but not in military contexts. This suggests that the interaction context shapes preferences.

Limitations and Future Opportunities

Binary and Dichotomous View of Gender

The literature relies heavily on a binary and dichotomous view of gender, measuring it by responses such as woman/man or female/male. Yet, scholars studying gender argue that gender is non-binary, continuous, and at times fluid (Fortunati and Edwards 2022; Lindqvist et al. 2021). Despite this, we could not find any papers attempting to employ other views of gender. Future research is needed that employs different views of gender to enrich our understanding. Suture studies can move beyond binary human gender categories as it is possible to design ambiguous, non-binary, and gender-fluid robots (Seaborn and Pennefather 2022a; Seaborn and Pennefather 2022b). For an example of ways to collect measures on gender and transgender see Spiel et al. (2019).

Designer's View of Gender

Most studies presented gendered robots based on the designer's perspective. Although manipulation checks may be able to confirm the designer's manipulations, people can have subconscious biases associated with body shape, facial features, movement, and other robot features (Bryant et al. 2020; Goetz et al. 2003). For example, although Pepper was given a male and female voice, McGinn and Torre (2019) found that its design was associated more with the female voice than with the male voice. This suggests that certain biases may not be detected during manipulation checks and necessitates more examination. This also provides an opportunity to examine the impact of robot gender-embodiment match/mismatch.

Gender Neutrality

Another approach that was not examined is robot gender neutrality. Gender-neutral robots have an absence or removal of gender (Seaborn and Pennefather 2022b). According to Seaborn and Pennefather, designing gender-neutral robots can remove any negative side-effects associated with robot gender. If this can be done, future research is needed to fully investigate whether such an approach is more problematic than beneficial. On one hand, if humans prefer what the studies termed "male security robots" (Tay et al. 2014; Tay et al. 2013), why not give them security robots self-identified as male? On the other hand, to do so means reinforcing a self-fulfilling cycle that stereotypes gender in our society. Future research could employ frameworks on robot gendering (Seaborn and Pennefather 2022a).

Interaction Settings

Studies in the review relied heavily on videos, pictures, and text. Only two studies (Tay et al. 2014; Tay et al. 2013), that are related, used actual interactions with robots, both in experimental settings. More field studies should be conducted to reliably generalize findings to actual interactions. Researchers should perhaps make use of immersive virtual environments to replicate real-life encounters to effectively explore and assess perceptions and behaviors toward security robots. One benefit of this is that researchers could identify repeatable, valuable elements of real interaction for future experiments.

Data for Meta-analysis

Future studies should report more data that can be used for meta-analysis. Meta-analyses can help overcome the limitations of any single study by quantitatively combining the results of multiple studies (Esterwood et al. 2021a; Esterwood et al. 2021b). For example, data could be used to understand whether gender interacts with other demographic factors in understanding security robot acceptance. We attempted to conduct a meta-analysis only to discover that many studies failed to report the needed data. Esterwood et al. (2022) provide a guide for conducting HRI meta-analyses and the information needed.

Conclusion

Security robots, which have been deemed cost-effective for law enforcement, prompt the need to examine gender's role in their acceptance. We conducted a brief literature review on the subject, categorizing findings into two research streams and highlighting gaps that need scholarly attention.

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