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The Influence of Gendered Physical Attributes and Personality Traits on Robot Perception

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Abstract
Social robots inevitably present multiple social cues simultaneously, yet previous research has generally examined these cues in isolation. The present study provides the first test of how a robot's gendered morphology and a gender-stereotyped perceived personality together shape task-suitability judgments, acceptability, likeability, and anthropomorphism. Our findings reveal that robots with masculine physical features are perceived as more suitable for tasks traditionally associated with masculinity than those with feminine morphological characteristics. However, no effect of robot physical characteristics was observed for feminine tasks. Critically, the study reveals an important phenomenon: people judge a robot as more anthropomorphic when its perceived gendered appearance matches the gender-stereotyped personality traits assigned to it. The results can inform designers who wish to boost anthropomorphism by matching appearance and behaviour, or, conversely, to challenge stereotypes or reduce the level of perceived anthropomorphism by deliberately mismatching them.

Keywords Robots · Gender · Personality · Artificial intelligence

1 Introduction

As robots become more prevalent in our personal lives and professional settings, performing a broad range of tasks from manufacturing to providing companionship, the development and implementation of robots with diverse form factors and personalized characteristics have expanded [1]. A notable trend across all fields is the integration of human-like characteristics in robot design, a concept often referred to as anthropomorphism in scientific literature [2, 3]. This trend capitalizes on the innate human propensity to attribute human traits to non-human entities, a tendency evident from a young age [4], and that can be considered a bias that influences human perception [5, 6].

Robots' developers often leverage this propensity by incorporating human-like features, such as a head [7], a face [1, 8], a communication style [9, 10], a body with limbs [11], and human-like movements into robots [12]. This strategy is based on the belief that human-like cues can facilitate more natural and intuitive interactions between humans and robots, drawing on familiar social cues and scripts from human interactions [13–16].

Recognizing robots as anthropomorphic systems also implies that they can be perceived and represented as systems with mental states [17], and be able to behave in a consistent style [9, 10], showing a personality [18]. Nonetheless, applying such an approach to human-robot interaction (HRI) might also inadvertently introduce and perpetuate social categorizations and stereotypes (including gender stereotypes) already prevalent in social interactions involving humans [19]. This is particularly relevant in how social interactions often revolve around binary categorizations, such as gender, which are frequently perceived as natural divisions despite being social constructs. Gender, along with race and ethnicity, is commonly seen as a fundamental category, influencing how individuals categorize others and, by extension, how they may perceive and interact with anthropomorphic robots [20, 21].

Simone Grassini and Stefano Guidi contributed equally to the scientific work and sharedthe first authorship.

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The present study examines how perceived personality stereotypes associated with a robot's designed gender cues and its physical appearance (male or female attributes) influence the roles considered suitable for robots featuring feminine or masculine morphological characteristics, as well as exploring potential factors affecting the perceived qualities of the presented robots.

1.1 Attribution of Gender to Robots

It can be argued that with time passing, gender stereotypes are diminishing but still retain considerable strength. A recent longitudinal study [22] spanning over 70 years and starting in the mid-1940s highlighted the maintenance of the stereotype that ascribes the trait of agency (the characteristic of being active, in control of actions, endowed with strength and courage, and able to pursue goals) relatively more to men than to women. Women, on the other hand, are increasingly stereotyped as characterized by the communion trait, i.e., as stereotypically sensitive, communicative, and affectionate. The study also noted, however, that over the decades, the belief that men and women can demonstrate equal skills, for example, in creative abilities and intelligence, has increased [22].

In the research area of HRI, specific designs strategically utilize the connection between assigned gender and the traditional characteristics of social roles, albeit this approach sometimes perpetuates existing gender stereotypes [23, 24]. Studies have shown that robots receive more positive evaluations and greater acceptance when their perceived gender, including voice and name, aligns with the stereotypical gender roles of their intended tasks, such as healthcare or security [24]. This alignment suggests that the perceived appropriateness of robots for specific jobs is influenced by their assigned gender [12]. For instance, roles typically associated with masculinity, such as security tasks, are often associated with robots that exhibit masculine morphological characteristics. In contrast, robots with feminine morphological characteristics are often associated with feminine roles, such as healthcare and domestic chores [24].

Furthermore, the gendering of robots is often rationalized by the associated purported benefits that align with human expectations. For example, robots with feminine morphological characteristics are thought to embody higher emotional intelligence, whereas robots with masculine morphological characteristics are perceived as more trustworthy, reliable, and competent [25, 26]. Such gender-specific perception underlines how deeply ingrained societal stereotypes about gender roles and characteristics can influence the design and reception of robots in various fields.

Researchers have raised questions about the necessity and implications of gendering robots, particularly considering concerns that this may perpetuate existing stereotypes associated with gender and occupation [27, 28]. The introduction of gender-neutral robots presents a potential avenue for mitigating these stereotypes. It has been shown [29] that trust in a robot's occupational competence does not differ significantly across male, female, and gender-neutral robots. However, it has been suggested [30] that gender neutrality might not be enough to safeguard robots from negative biases. Scientific research has also highlighted the significance of the context in which a robot operates on users' preferences for its level of anthropomorphism, suggesting that the setting influences the desired degree of human-like features in robots [19]. Despite the potential benefits of avoiding gender assignments in robot design, unintended biases related to social stereotypes may still emerge [26, 31]. Robots designed without explicit human-like gender indicators might still be categorized as male or female based on occupational stereotypes or even the robot's form factor. This categorization issue is reinforced by the dominance of men in technology development and the historical association of physical strength and computational power with masculinity [32, 33]. However, this bias is not merely a matter of individual cognitive predisposition or the demographics of design teams. It is also shaped by the broader sociotechnical context, in which specific cultural perspectives and values are embedded in the technology's design and intended use cases. When certain viewpoints are prioritized during the development process, they create systemic structural expectations that favor masculine interpretations of robotic agents. Consequently, there is often an implicit bias toward perceiving robots (especially in the case of those robots displaying high levels of anthropomorphism) as male [19, 34].

1.2 Attribution of Personality to Robots

A comprehensive review of 83 empirical HRI studies that maps how personality is conceptualized for both humans and robots and synthesizes the behavioral consequences of these conceptualizations [35]. The study identified four major research thrusts: the effects of human personality, the effects of robot personality, the influence of similarity or difference between the two, and contextual factors that shape the perceived robot personality. The review shows that extraversion versus introversion is the most frequently examined trait dimension and that personality congruence between user and robot tends to enhance trust, engagement and task performance.

Research exploring the effect of personality attribution to robots and its impact on HRI is rapidly growing. Notable, a published research [24] investigated how the perceived personalities of robots, based on their assigned roles (security vs. healthcare) and gender (male vs. female), influence human interactions. This study found a preference for robots with extroverted personalities in healthcare roles and introverted personalities in security roles. Moreover, it highlighted that robots whose gender and personality traits align with traditional stereotypes associated with their occupational roles tend to be preferred.

A more recent study [36] studied whether robots that exhibit a stereotypical gender and personality coherence with their tasks (for example, a female-cooperative robot assigned to help and assistance tasks) are more positively received in terms of technological acceptance than those presenting a mismatch (such as a male-competitive robot in help and assistance roles). The findings revealed that the female-cooperative configuration had a more significant impact on technological acceptance for the specified front-office service tasks than the male-competitive setup. However, this study also suggested that, within the context of these service tasks, gender appears to play a more critical role than personality in achieving a conceptual coherence with stereotypes. The authors suggest that aligning gender and personality stereotypes with the tasks performed by social robots leads to a more natural interaction experience, activated through what they refer to as perceptual fluency [37]. This means that when robots exhibit characteristics that match their intended roles, it may ease human interaction with them, as these characteristics resonate with pre-existing societal stereotypes, making the robots' behaviours and roles more predictable and understandable to humans.

1.3 The Present Study

The present study investigates whether a match (or mismatch) between a robot's gendered appearance and its gender-stereotyped personality profile affects how people perceive the robot, with a focus on anthropomorphism and perceived task suitability. Understanding these effects is crucial for the acceptance of future robotic systems, especially as robots increasingly integrate advanced AI that can emulate human-like personality traits [38]. Based on this aim, we investigated the following three research questions:

RQ1 How do a robot's designed gender cues shape judgments of its suitability for tasks that are culturally coded as masculine or feminine?

RQ2 How do gender-typed personality descriptions shape those same task-suitability judgments?

RQ3 Do designed gender cues and gender-typed personality descriptions interact to influence task suitability and broader evaluations such as acceptability, likeability, and anthropomorphism?

Guided by the research questions, the following hypotheses were quantitatively tested:

Hypothesis 1 (H1) Robots with feminine/masculine morphological characteristics will be evaluated as more adequate for the corresponding gender roles.

Hypothesis 2 (H2) Robots personality characteristics interact with robot morphological characteristics: when robot morphology matches the described stereotypical personality traits the robots are perceived more positively for the study variables of interest.

Hypothesis 3 (H3) Positive general attitude toward technology, as well as familiarity with technology and tendency to anthropomorphism positively correlate with a positive attitude towards robots.

2 Method

The present study's method, hypotheses, and analysis plan were pre-registered prior to data collection. The pre-registration document can be accessed on the Open Science Framework (OSF) by following the link: https://osf.io/7v9nk/?view_only=458210e818e94c41a59d421255efdf5d.

Please note that the pre-registration relates to a more extensive research endeavour, of which the current study represents one phase. The first three hypotheses stated in the pre-registration have been tested in the current article. Hypotheses on the relationship between variables not explicitly presented in the pre-registration are defined as exploratory in the article.

The study was conducted in line with the recommendations of the Declaration of Helsinki for a study involving human participants and following local and national regulations concerning ethics and data management concerning this type of scientific research (University of Bergen, Norway)

2.1 Participants

Three hundred and twenty-nine participants, evenly split by gender from a location kept anonymous for peer-review purposes, were enrolled in the study. The average age of the participants was 34.3 years (SD = 11.1).

Recruitment was conducted via the online platform Prolific (prolific.com), where participants were compensated with a participation fee (around 1.20 euros) for completing an online survey presented through Lime Survey™. Each participant was then randomly placed into one of six experimental groups. These groups were defined by the visual presentation of one of two robots, each featuring either feminine or masculine morphological characteristics, and one of three personality description alternatives: a stereotypically positive male personality description, a stereotypically positive female personality description, or the absence of any personality description. The participants, on average, completed the survey in 6 minutes. A G-power analysis showed that a sample size of 300 participants would allow for the detection of a medium-small sized (f = 0.184) main effect of robot personality or a medium-small sized interaction between robot gender and robot personality with power ≥ 0.8. And to detect a similarly sized main effect of robot gender with power ≥ 0.89. We oversampled by 10% in expectancy of discarding some participants for failing the attention checks or missing data.

2.2 Robots and Descriptions

Our objective was to obtain images of robots for the experiment that were visually similar yet differentiated by gender-specific attributes. To achieve this, we utilized the image generation capabilities of DALL-E 3 [39], as integrated within ChatGPT-4 [40]. We requested the AI service to produce images of two humanoid robots, visually comparable but distinct in terms of gender characteristics, specifying one version to exhibit male characteristics and the other female characteristics. To ensure consistency and provide a reference point for the desired level of human likeness and physical appearance details, we supplied the chatbot with the image of an example robot named "Romeo" taken from the ABOT database [11]. We generated four images, two of a masculine robot and two of a feminine one. Each robot was rated by 20–22 participants in a pre-test on masculinity and femininity (using 7-point scales), age, and human likeness (on continuous scales ranging from 1 to 100). We then selected one masculine robot (Mean masculinity = 6.7, Mean femininity = 1.2, Mean age = 29.5, Mean human likeness = 4.3) and one feminine robot Mean masculinity = 1.4, Mean femininity = 6.3, Mean age = 27.9, Mean human likeness = 4.4) that differed significantly in perceived gender, but not in perceived age and human likeness (Fig. 1).

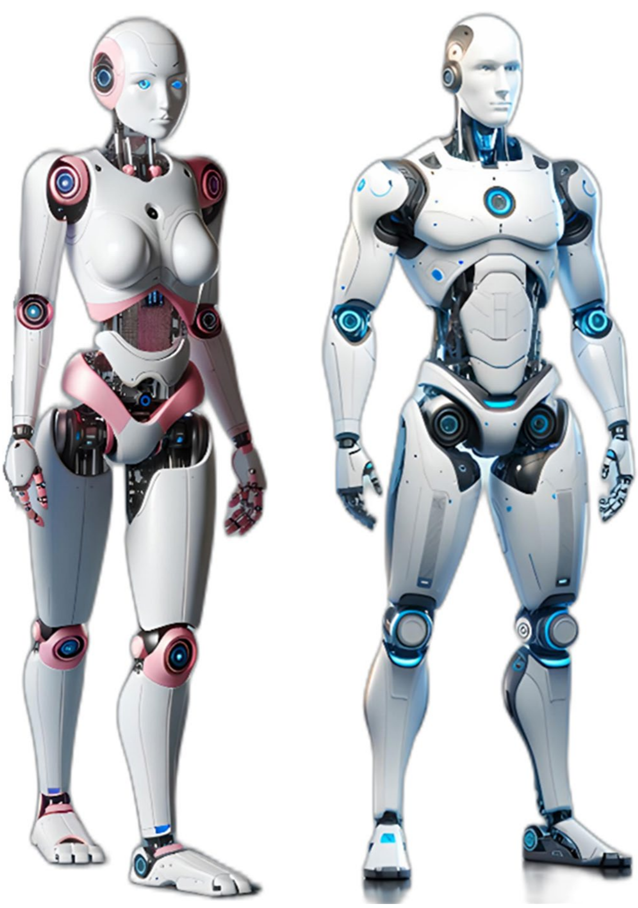

Fig. 1 Robots that were selected for inclusion in the experiment

We formulated two personality profiles to be experimentally assigned to the robots, one anchored in stereotypically positive male traits and the other in stereotypically positive female traits, drawing from the positive attributes identified in gender-related research [41]. Building upon the framework provided by Grysman and Booker [42], which distinguished between socially desirable traits typically associated with femininity (emphasizing communion) and masculinity (emphasizing agency), we selected five traits for each gender profile, chosen for their likely positive reception across various cultural contexts. The adjectives chosen to represent masculine stereotypical positive traits were "independent," "decisive," "never gives up," "self-confident," and "stands up under pressure." For the feminine stereotype, the selected adjectives were "gentle," "helpful," "kind," "understanding," and "aware of feelings."

We then produced realistic descriptions for a hypothetical robot prototype, referred to as G01T, which were presented to study participants. These descriptions were carefully designed to reflect the selected personality traits:

For the experimental condition that included the positive masculine stereotype personality, we presented G01T as follows: "We are designing G01T so that it has a truly independent character. G01T has a special talent for expressing decisiveness and self-confidence. In interactions, it will always show a desire to act and will never give up. This will make G01T able to behave with a lot of independence and capable of making decisions, especially in situations where it is necessary to stand up under pressure."

For the experimental condition that included the positive feminine stereotype personality, we described G01T as follows: “We are designing G01T so that it is truly aware of feelings. G01T has a special talent for expressing warmth and being helpful. In interactions, it will always show friendship and behave gently. This will make G01T very sensitive and capable of being kind, especially when it is necessary to be understanding.”

Participants could also be presented with an image of a robot featuring feminine/masculine morphological characteristics without any associated personality descriptions. This condition was intended to serve as a control, allowing for the assessment of baseline perceptions of the robots without the influence of personality descriptions.

2.3 Procedure

From the prolific platform, participants were directed to the online survey, where they were initially informed about the study’s objectives, the nature of the procedure, and their right to withdraw. Once they had expressed informed consent, the system randomly allocated the participants to one of the six experimental groups. They were presented with one of the two robots’ images and one of the three alternatives for the description (masculine stereotype personality, feminine stereotype personality, no information). They were then asked to respond to a battery of questionnaires aimed at understanding their perception of the robot and how they believed the robot was adequate for different tasks. The participants were then asked to report their demographic information and respond to other questions related to their opinions, experiences, and attitudes.

2.4 Instruments

The study included a series of questionnaires intended to evaluate participants’ pre-existing attitudes towards robots, their familiarity with robots and related technologies, their tendencies towards anthropomorphism, and their impressions about the robots presented. To understand the acceptability of robots, 3 items from previous studies [36] were adapted to form an Acceptability Questionnaire specific to the robots presented in this study. The questions were asked to rate on a 7-point scale (1 = “absolutely no”, 7 = “absolutely yes”) whether participants would “trust G01T”, “like to interact with G01T” and would “accept its help for study, work or other activities”. The answers to these questions were averaged to yield a single measure ($\alpha = 0.88$).

To measure participants’ perceptions of the adequacy of robots for stereotypical gender tasks, we used 10 items adapted (the adaptations from the original scale are reported within square parentheses in the text) from [12], answered on a 7-point scale (ranging from 1 = not suited at all to 7 = extremely suited). Five items concerned the suitability of the robot for stereotypical masculine tasks (“navigating a route” [added in reference to stereotypes about gender and wayfinding], “repairing a bike” [modified from “repairing technical equipment”], “steering a car” [modified from “steering machines” to leverage on the stereotype about gender and cars/mechanics], “performing surgery” [added], “guarding my home”, Cronbach’s $\alpha = 0.82$), and 5 the suitability for stereotypical feminine tasks (“caring for a child”, “keeping up the household”, “preparing meals”, “providing therapy” [modified from “patient care”], “taking care of elderly”, Cronbach’s $\alpha = 0.84$).

Furthermore, the Godspeed scale [43] was utilized to measure perceptions of robots across four domains: likability (Cronbach’s $\alpha = 0.85$), anthropomorphism (Cronbach’s $\alpha = 0.79$), perceived intelligence (Cronbach’s $\alpha = 0.85$), and animacy (Cronbach’s $\alpha = 0.8$). Participants’ general attitudes towards robots were measured using an adapted version of the AI Attitude Scale [44] (AIAS-4, Cronbach’s $\alpha = 0.93$). In contrast, the Individual Differences in Anthropomorphism Questionnaire (IDAQ) was used to assess the extent to which participants attribute human-like qualities to non-human agents [5] (Cronbach’s $\alpha = 0.82$). Four questions collected information about participants’ familiarity with robots, AI systems, Information Technologies and science fiction. The answers were scored on a 7-point agreement scale and averaged to form a single measure (Cronbach’s $\alpha = 0.77$). Basic demographic information, including age, gender, and country of residence, was also collected to analyze data concerning various demographic groups.

These questionnaires were chosen as they are widely employed in HCI. Furthermore, these instruments, being relatively short, were selected to minimise participant burden, which helps maintain data quality, especially in an online experiment.

2.5 Statistical Analyses

The data were analyzed using ANOVA and ANCOVA, including as dependent variables the scores for the measures of robot perception (Trust/acceptability, anthropomorphism, animacy, likeability, intelligence), *robot gender*, and *robot personality* as independent variables (2x3), and as covariates tendency to anthropomorphism (IDAQ), attitudes toward AI and robotics (AIAS-4), and familiarity with robots and related technologies (FRT). All the covariates were centered on the mean. In further models we also included participants’ gender as a covariate in interaction with the other factors, after removing non-binary participants. To examine the suitability of gender-stereotypical tasks, we conducted further analyses, including task gender as an additional within-subjects factor in the models.

Statistical analyses were performed using R (v0.4.4.2) and the functions in the packages *afex* and *emmeans*.

3 Results

A total of 329 participants completed the questionnaire. Among the respondents, we excluded the data from 15 participants who failed one (1st AC: 2, 2nd AC: 14) or two (1) attention checks included in the survey. Therefore, the final sample included 314 participants.

The mean age of the participants was 34.3 years (SD = 11.1), and their ages ranged from 20 to 72 years. 49.8% of participants were females (N = 156), 48.9% were males (N = 153), and 4 participants identified with a non-binary gender (1.28%). Male participants showed higher familiarity with robots and IT technologies (FRT: M = 4.93, SE = 0.09) and better attitudes toward robots (AIAS-4: M = 6.96, SE = 0.16) than women (FRT: M = 4.18, SE = 0.09, t(307) = 5.665, p < 0.0001; AIAS-4: M = 5.93, SE = 0.16, t(307) = 4.51, p < 0.0001). A MANOVA including experimental condition (6 levels) as independent variable and all the covariates as (combined) dependent variables were not significant, F(7, 306) = 1.656, p = 0.119.

3.1 Suitability for Gendered Tasks

We analyzed the perceived suitability of the robot to gendered tasks in a 3-way mixed ANCOVA, including stereotypical task genderedness (masculine or feminine) as a within-subject factor and *robot gender* and *personality* as between-subject factors. The results showed a significant main effect of *task genderedness* (F(1, 305) = 63.39, η^2 = 0.172, p < 0.001), a significant interaction between *task genderedness* and *robot gender* (F(1, 305) = 17.27, η^2 = 0.054, p < 0.001), and a significant interaction between *task genderedness* and *robot personality* (F(2, 305) = 6.46, η^2 = 0.041, p = 0.002).

Suitability ratings were higher for masculine tasks (M = 4.53, SE = 0.07) than for feminine tasks (M = 4.04, SE = 0.07, t (307) = 7.96, p < 0.0001). The analyses of the simple contrasts (Fig. 2A) showed that for masculine tasks, the feminine robot (M = 4.29, SE = 0.10) was rated as less suitable than the masculine robot (M = 4.78, SE = 0.10, t(303) = −3.430, p = 0.001), while for feminine tasks, the ratings for the feminine robot (M = 4.06, SE = 0.10) and for the masculine robot (M = 4.06, SE = 0.10, t(305) = 0.238, p = 0.812) were not significantly different. The analyses of the simple contrasts for the interaction between *task genderedness* and *robot personality* (Fig. 2B) showed that only for masculine tasks the robot with feminine traits (M = 4.33, SE = 0.12) was rated as less suitable than the robot with masculine traits (M = 4.76, SE = 0.12, t(305) = −2.55, p = 0.031), while for feminine tasks, the suitability of the robot with the feminine traits (M = 4.13, SE = 0.12) was not rated significantly different from the one of the robot with the masculine traits (M = 4.03, SE = 0.12, t (305) = 0.570, p = 0.836). Figure 2 presents an overview of the results, while Fig. 3 shows the mean scores for suitability individually for the different tasks proposed in the study.

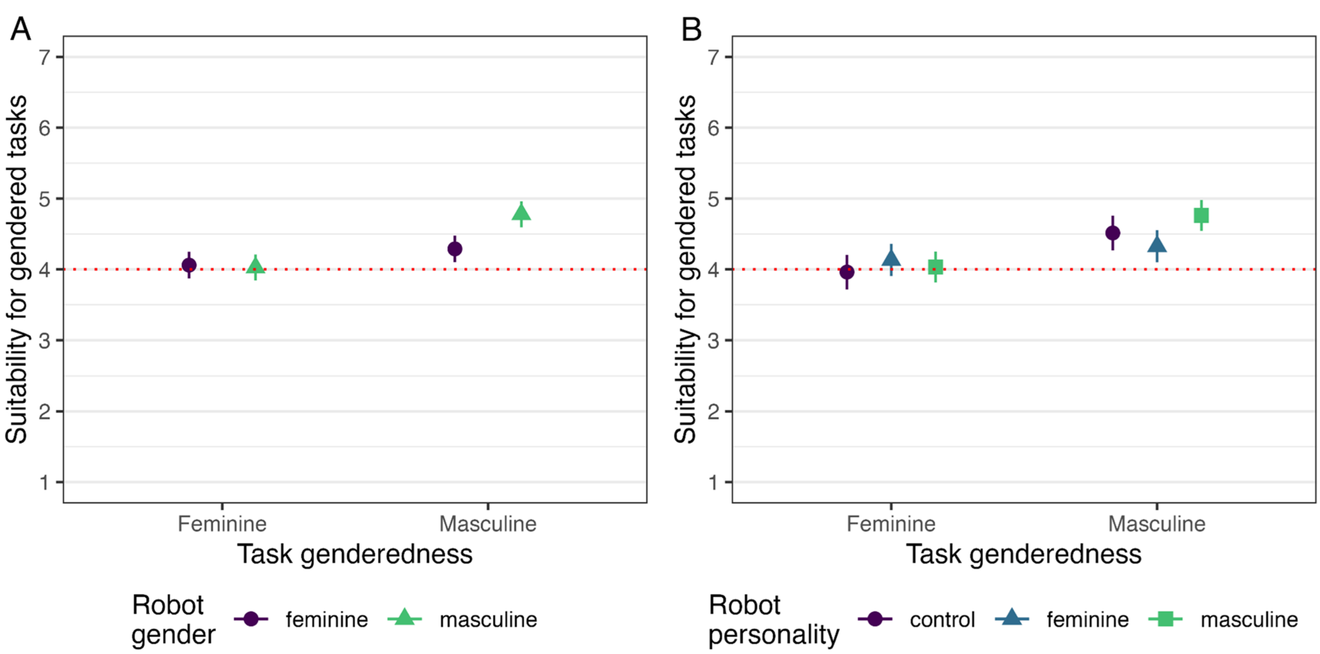

Fig. 2 Plots of the average perceived suitability of robots to gendered tasks as a function of (**A**) task genderedness and *robot gender* and (**B**) task genderedness and robot personality. Error bars are between-subjects 95% confidence intervals for the means

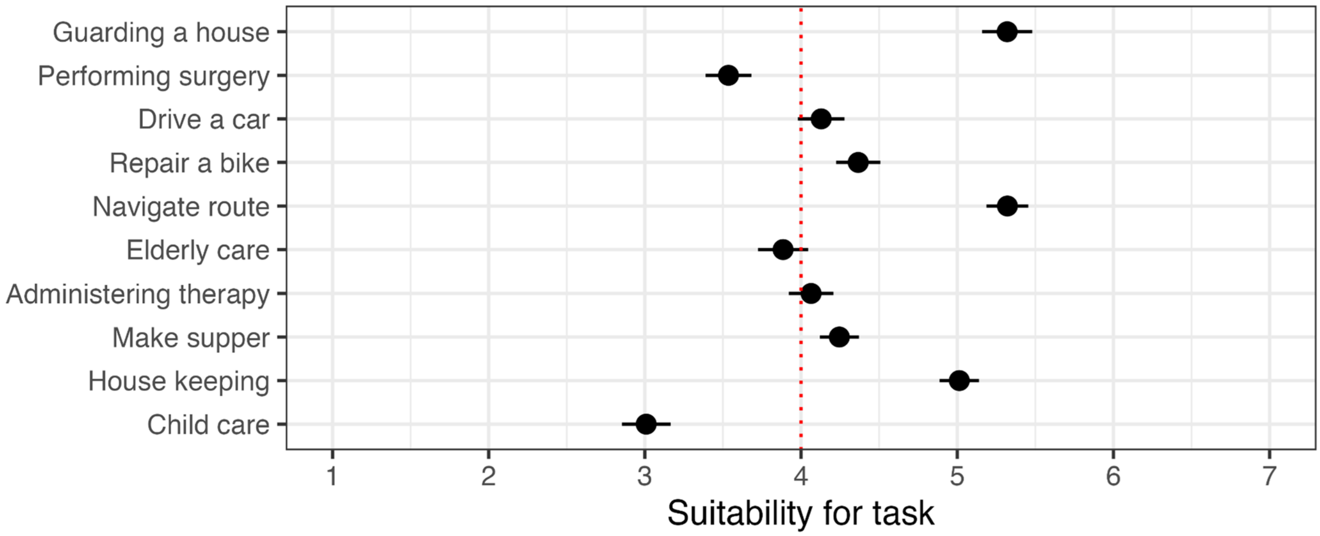

Fig. 3 Plots of the average perceived suitability of robots for the tasks included in the present study. In the list, the first five tasks represent stereotypically masculine ones, while the following five tasks represent stereotypically feminine ones

Further pairwise comparisons showed that only in the condition in which the robot was feminine in both personality traits and morphological features, it was not significantly considered more suitable for masculine tasks (M=4.08, SE=0.18) than for feminine tasks (M=4.21, SE=0.18, t(305)=0.80, p=0.425).

3.1.1 Effect of Participants' Gender

Concerning the effect of participant gender, the results of the 4-way ANOVA in which this covariate was included as factor, in interaction with the other three factors, showed the same significant main effects and interactions found in the 3-way ANOVA, but also revealed three additional marginally significant interactions: between *participant's gender* and *task genderedness* (F(1, 211)=3.39, η^2=0.016, p=0.067), between *participant's gender* and *robot gender* (F(1, 211)=2.78, η^2=0.015, p=0.078), and between *participant's gender, task genderedness* and *robot gender* (F(1, 211)=3.33, η^2=0.016, p=0.069).

The analysis of the simple contrasts for *robot gender* at the combinations of the levels of *task genderedness* and *participant's gender* (Fig. 4) revealed that men considered the masculine robot (M=4.67, SE=0.20) significantly more suitable than the feminine robot (M=4.02, SE=0.17), but only for stereotypically masculine tasks (t(211)=2.504, p=0.013). Women, conversely, tended to rate the feminine robot (M=4.27, SE=0.18) more suitable than the masculine robot (M=3.85, SE=0.17), but only for feminine tasks (t(211)=−1.693, p=0.092).

3.2 Acceptability and Likeability

In the analysis of the perceived trust and acceptability of the robot, neither *robot gender* (F(1, 305)=0.07, η^2=0.000, p=0.787) nor *robot personality* (F(2, 305)=0.68, η^2=0.004, p=0.504) was significant. The *robot gender* x *robot personality* interaction was also not significant (F(2, 305)=0.60, η^2=0.004, p=0.550).

The analyses of the likeability of the robots showed a marginally significant effect of *robot gender* (F(1, 305)=3.47, η^2=0.011, p=0.064), with the robots displaying feminine morphological characteristics (M=3.48, SE=0.05) rated as more likable than the one displaying masculine ones (M=3.35, SE=0.05, t(305)=1.862, p=0.064).

3.3 Anthropomorphism, Animacy, and Intelligence

The analysis of the perceived robot anthropomorphism showed a significant interaction between *robot gender* and *robot personality* (F(2,305)=4.95, η^2=0.031, p=0.008), but no significant main effects of *robot gender* (F(1,305)=0.65, η^2=0.002, p=0.422) or *robot personality* (F(2,305)=0.52, η^2=0.003, p=0.598). The analyses of the simple contrasts on *robot gender* (Fig. 3) showed that perceived anthropomorphism was higher for robots in which gender matched the personality (Feminine personality: M_{FR}=2.48, SE=0.10, Masculine personality M_{MR}=2.41, SE=0.10) than for robot in which gender and personality traits did not match (Feminine personality: M_{MR}=2.17, SE=0.10, t(305)=2.05, p=0.041, Masculine personality M_{FR}=2.14, SE=0.10, t(305)=1.94, p=0.053). In the control condition, instead, the result showed a non-significant tendency to perceive masculine robots (M_{MR}=2.34, SE=0.10) as slightly

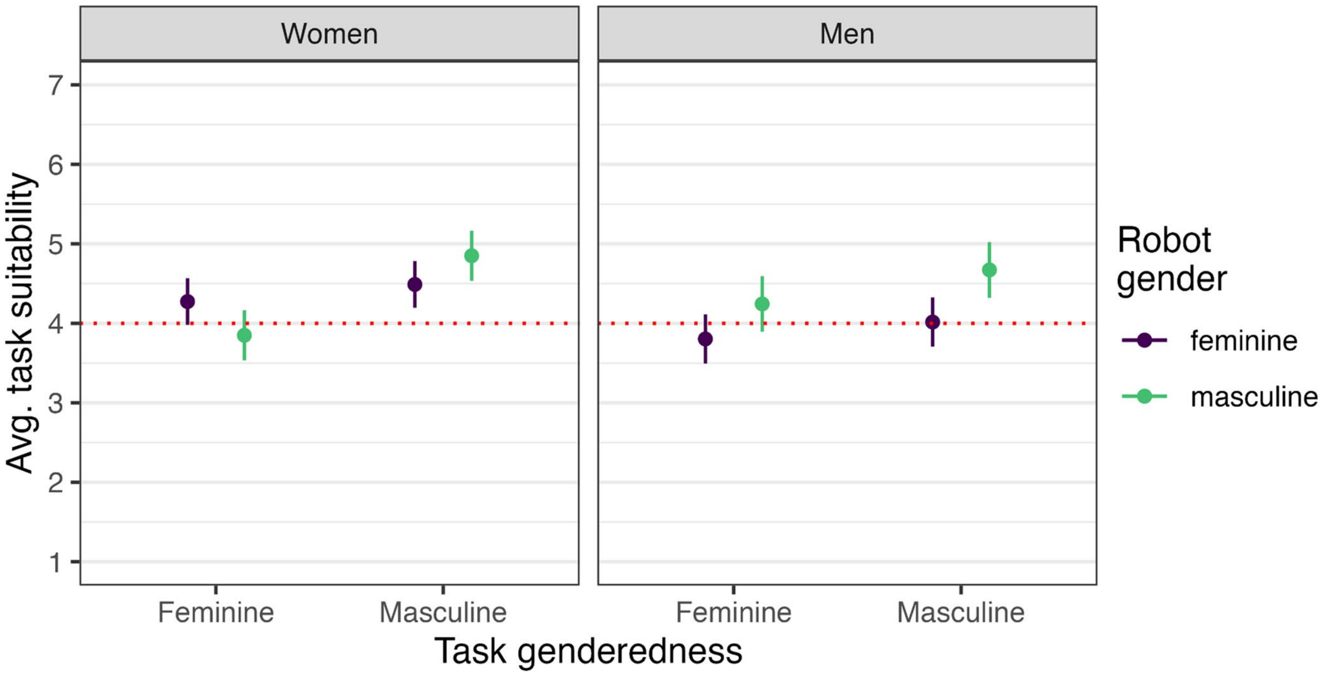

Fig. 4 Plots of the average perceived suitability of robots to gendered tasks as a function of robot gender, task genderedness and participant's gender. Error bars are 95% confidence intervals for the means for the groups

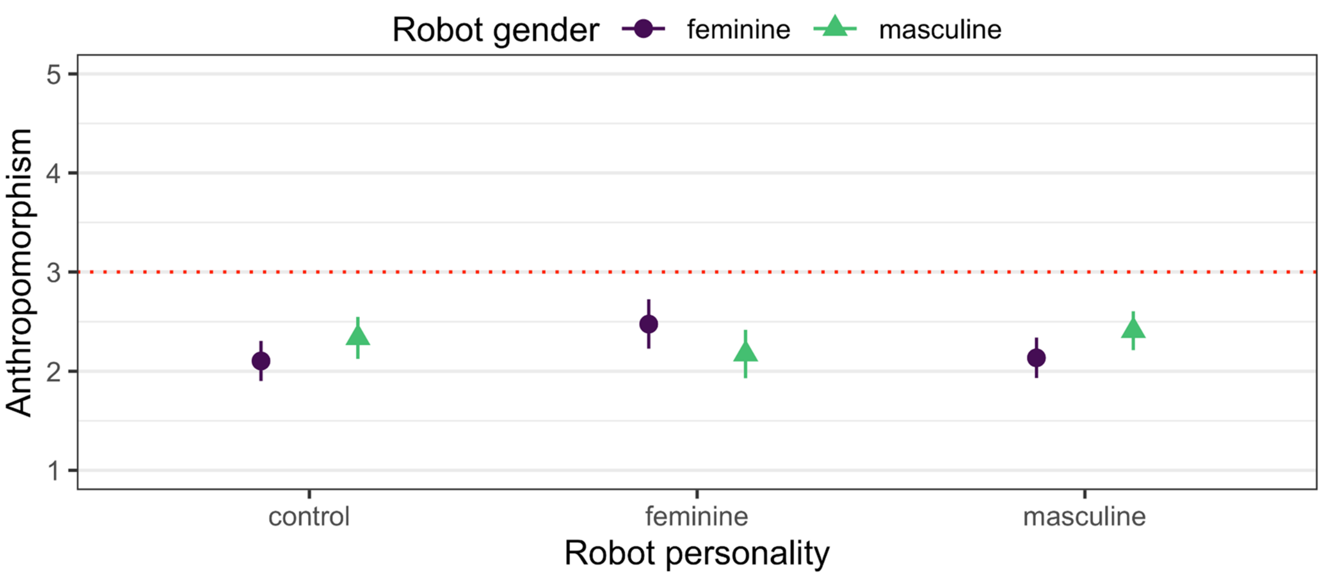

Fig. 5 Plots of the perceived anthropomorphism of the robot as a function of *robot gender* and *personality*. Error bars are 95% between-subjects confidence intervals for the means

more anthropomorphic than feminine robots (MFR = 2.10, SE = 0.10, t(305) = −1.58, $p = 0.113$). The effect of robots' attributed personality and physical features on anthropomorphism is presented in Fig. 5.

No significant effects of *robot gender*, *robot personality*, or their interactions were found in the analyses of the perceived animacy (*robot gender*: F(1,305) = 0.06, $\eta^2 = 0.001$, $p = 0.802$, *robot personality*: F(2,305) = 0.51, $\eta^2 = 0.003$, $p = 0.601$, *robot gender* x *robot personality*: F(2,305) = 0.88, $\eta^2 = 0.006$, $p = 0.415$) and intelligence of the robots (*robot gender*: F(1,305) = 0.55, $\eta^2 = 0.002$, $p = 0.461$, *robot personality*: F(2,305) = 2.24, $\eta^2 = 0.014$, $p = 0.109$, *robot gender* x *robot personality*: F(2,305) = 0.004, $\eta^2 = 0.000$, $p = 0.996$). The mean scores for anthropomorphism in all groups were relatively low, ranging from 2 to 2.5.

3.4 Effects of the Covariates

Among the covariates, AIAS-4 was significantly and positively associated with all the dependent variables ($B_{FT}=0.23$, $B_{MT}=0.13$, $B_{Acc}=0.46$, $B_{Ant}=0.13$, $B_{Anim}=0.13$, $B_{Lik}=0.16$, $B_{Int}=0.11$, all ps<0.01-0.001), IDAQ was significantly associated with Suitability to stereotypically Masculine Tasks (SMT) (B=0.12, $p=0.035$) and with intelligence (B=0.08, $p<0.01$).

Participants' gender had only a marginally significant effect on perceived trust ($F(1,297)=3.70$, $\eta^2=0.012$, $p=0.055$) and likeability ($F(1,297)=3.42$, $\eta^2=0.011$, $p=0.065$), with women tending to express lower ratings for both variables. For intelligence ratings only the analysis revealed a significant interaction between *participants' gender* and *robot gender* ($F(1,297)=5.20$, $\eta^2=0.017$, $p=0.023$), and the results of the test of the simple effects of *robot gender* separately for men and women revealed that women considered the feminine robot less intelligent ($M=3.57$, SE=0.08) than the masculine robot ($M=3.84$, SE=0.08, $t(297)=-2.313$, $p=0.021$, d=0.13), while men did not consider the feminine ($M=3.68$, SE=0.08) and the masculine robot ($M=3.57$, SE=0.08) significantly different in intelligence ($t(297)=0.919$, $p=0.359$).

4 Discussion

The present study aimed to understand how humans perceive robots based on the interaction of their physical and personality characteristics. We first hypothesized that the gender of a robot would influence how it is considered suitable for different tasks (H1). The results of our study partially support this hypothesis, as we found that for masculine tasks, a masculine robot was perceived as significantly more suitable than a feminine robot. However, for feminine tasks, no significant differences were found in the suitability of robots with different genders. This contrasts with previous studies, which found that a feminine robot is preferred to or considered more suitable for feminine tasks than a masculine robot [12, 45]. The discrepancy between the results of these studies and those of the present one may be related to the degree of human likeness of robots. Parlangeli and colleagues [46] demonstrated that for feminine robots, perceived adequacy for feminine tasks was only observed for highly human-like robots, but not for those low in human-likeness.

In contrast, for masculine robots, the degree of human-likeness did not moderate the preference for gender-matching tasks. The level of human-likeness of the robots used in our experiments (which was equivalent) was too low to allow for an effect of the feminine morphological characteristics. Consistent with previous studies [30, 45], we also found that both robots were perceived as significantly more suitable for masculine than feminine tasks.

Overall, our results suggest that neither a feminine nor a masculine robot is considered suitable for feminine tasks. In contrast, for masculine tasks, all robots are more suitable, particularly when they possess masculine morphological features. This could be due to a general bias in perceiving robots as male, as previously proposed [45, 46]. However, this finding must be interpreted with caution. The feminine tasks used in this study (e.g., therapy and childcare) are more relational and culturally nuanced than the more mechanistic masculine tasks (e.g., bike repair and surgery). This conceptual imbalance may indicate that the perceived suitability for feminine tasks was influenced by the subjective complexity of those tasks, rather than by a lack of gendered perception. The finding that masculine morphological features enhanced suitability for masculine tasks, whereas feminine features did not enhance suitability for feminine tasks, may reflect these deeply embedded sociotechnical values. It may suggest that the "default" robotic agent remains conceptually tied to masculine archetypes.

Additionally, we found that task gender interacted with robot personality, so for masculine tasks, providing feminine personality traits made the robot less suitable than providing masculine personality traits. This partially supports our second hypothesis. Based on previous studies [24], we hypothesized that robots' personality characteristics would interact with robot morphological characteristics so that when robot morphology matches the described stereotypical personality traits, the robot would be perceived more positively (H2), concerning likeability and trust/acceptability (primary hypotheses), and possibly also concerning intelligence, agency, and anthropomorphism (exploratory hypotheses). However, concerning task suitability, an effect of personality was only found for masculine tasks but not for feminine tasks. Moreover, we found only slight biases in favour of liking a robot with a female gender or personality more than a robot with a male gender or personality (biases previously documented in research). The exploratory hypothesis that a gender-personality match could affect other dimensions of robot perception was supported in the case of perceived anthropomorphism, which was consistently higher when the robot's gender matched i*ts personality* than when it didn't. When no personality description was provided, the perceived anthropomorphism of the masculine and feminine robots did not differ significantly. Overall, our results suggest that perceiving a gendered robot may activate stereotypical expectations regarding its personality traits (and vice versa), such that the robot is judged as more realistic and human-like when these expectations are met and less so when they are not met. However, the lack of a significant interaction between robot gender and personality in the ratings of trust and likeability does not support the hypothesis [36] that positive perception of robots may be related to perceptual fluency [37].

Our last hypothesis (H3) was that individual attitudes and familiarity with robotic technology, as well as individual tendency to anthropomorphism, would positively correlate with acceptability, as has been previously shown [24, 45]. Our results partially support H3. Consistent with previous research, positive attitudes toward technology and robots increase the acceptability of robots. Still, greater familiarity with the domain doesn't, suggesting that individuals' attitudes play a predominant role in shaping how participants perceive the robots. As for the effect of the tendency to anthropomorphisms, our results showed its impact to be limited, as it was positively associated with perceived intelligence and the perceived suitability of the robots to masculine tasks, but not with perceived anthropomorphism or with the other robot perception dimensions. However, the two scales we used, IDAQ [5] and the Godspeed Questionnaire [43], are based on different conceptions of anthropomorphisms, which might thus explain the lack of association.

In addition to examining the differences between the groups, it is essential to consider the absolute scores as revealed in our analyses. As shown in Fig. 4, although there were no significant differences between the groups regarding anthropomorphism, the scores for all groups ranged from 2 to 2.5 on the scale. These low scores indicate that, regardless of the gender or personality traits attributed to robots, participants generally perceived them as having a low level of human-like characteristics. This suggests a potential limitation in the design or presentation of the robots, which may not have effectively conveyed anthropomorphic qualities to the participants.

Similarly, the absolute scores for the perceived suitability of robots for masculine and feminine tasks were relatively modest (Fig. 2). This suggests that, although differences existed based on the robots' gender and personality traits, participants did not strongly endorse the robots as highly suitable for either type of task. These findings highlight skepticism or reservations about the robots' capabilities, potentially influenced by inherent design limitations or pre-existing biases towards anthropomorphic robots.

The moderating influence of participant gender reinforces the role of gender-congruent cues in shaping evaluations of robotic partners. Male participants rated the masculine robot as more suitable than the feminine robot when judging stereotypically masculine tasks, while female participants showed a parallel, though non-significant, inclination to prefer the feminine robot for feminine tasks.

5 Limitations and Conclusions

Our study has several limitations that must be acknowledged. Firstly, we used a convenience sample recruited online, which comprised primarily of young people who generally hold more positive views and attitudes toward technology than the general population [47]. However, participants' age did not significantly shape attitudes toward recently developed technologies, as is the case with AI [48]. Whether these findings can be generalized to more diverse samples remains an open question. A significant limitation of the current study concerns the conceptual asymmetry between the sets of tasks used to represent gender stereotypes. The tasks categorized as masculine (e.g., repairing a bike or steering a car) are primarily mechanistic and concrete, leading to a high degree of interpretative consistency among participants. In contrast, the feminine tasks (e.g., providing therapy or caring for a child) are inherently more relational, subjective, and culturally contingent. This lack of operational equivalence may have introduced interpretative noise. It is possible that the null effects observed for feminine tasks do not reflect an absence of gendered association, but rather the increased ambiguity and varied personal expectations associated with care-oriented and social roles. Future research should aim for more parallel task operationalization, for example, by including feminine-stereotyped tasks that are more mechanistic or masculine-stereotyped tasks that are more relational, to ensure a balanced comparison across gender domains. Another limitation concerns the way personality was manipulated and the specific personality profile employed. Furthermore, we relied on explicit sets of adjectives corresponding to different traits, stereotypically masculine or feminine. Other, more indirect ways of manipulating the robot's personality might have different effects, possibly stronger, since they could bypass participants' eventual biases toward providing socially desirable responses. Lastly, we used only images of robots. While, for the sake of investigating how gender features could activate gender stereotypes, this approach may be sufficient, the results might have been different if we had used images of real robots or videos.

A further important limitation of this study relates to the specificity of the visual stimuli used. In manipulating the robot's gendered appearance, other visual cues beyond gender were invariably altered, including body form, color, posture, and facial expression. For instance, the masculine robot's broad-shouldered frame and the feminine robot's use of pink accents are confounding variables, making it difficult to isolate the effect of perceived gender from the effects of these other design elements. While our pilot test ensured that the stimuli differed in perceived gender while controlling for variables such as perceived age and human-likeness, we acknowledge that other uncontrolled confounds remain.

In conclusion, the results of our study suggest that the assigned gender of a robot, as well as its personality traits, can each influence its acceptability, albeit to a limited extent. Furthermore, assigning genders and personality traits to robots is not yet fully able to overcome a general tendency to view robots as male entities that are generally more suitable for masculine than feminine tasks. In our study, only when a feminine robot was also given a feminine personality, there was consistency between the gendered morphological features and expected personality traits. In this case, the robot was not considered more adequate for masculine tasks. However, our findings indicate that the combination of feminine morphological and personality traits primarily diminishes the perceived suitability of robots for masculine tasks rather than enhancing their suitability for feminine tasks, which remains limited. This suggests that robots may currently be less acceptable for roles traditionally viewed as feminine. Therefore, attributing feminine traits to robots may have limited benefits for increasing their acceptance in these roles and could negatively impact their perceived adequacy for other tasks.

Taken together, the results indicate that embodiment cues and scripted personality should be treated as interdependent design levers. Designers who seek high anthropomorphism can align the two; those who wish to reduce it may deliberately misalign them. The findings also motivate the development of adaptive interfaces, in which a robot modulates its displayed personality in real-time to suit situational goals and user expectations.

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Data Availability The dataset supporting the findings presented in this article is available in Open Science Framework (OSF), following this link: https://osf.io/3ayu6/?view_only=9e2dc930aeaf4c8bb53ebaa9e842d44c.

Declarations

Ethical Approval The authors declare no conflict of interest. This study involved human participants and was carried out in accordance with the Declaration of Helsinki and relevant national and international regulations following the University of Bergen's guidelines for research of this kind. Before beginning the online survey, all participants were explicitly asked to accept their participation and read the informed consent.

Competing Interests The authors declare no competing interests. The study was performed in line with local and international guidelines concerning studies on human participants.

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