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Adaptive Affordance Design for Social Robots: Tailoring to Role-Specific Preferences

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***Abstract*—As social robots become integral to diverse interaction scenarios, their design must effectively engage users emotionally while accurately conveying their functional capabilities through coherent design. While previous research in adaptive human-robot interaction has predominantly focused on enabling robots to learn and adapt to users' dynamic behavior, less attention has been paid to robots' affordances. This study addresses this gap by investigating how users' preferences for a social robot's affordances, such as look and voice, vary across different social roles and scenarios. Using the Stereotype Content Model's dimensions of warmth and competence, we conducted a quantitative survey with Likert-scale measures to assess preferences for affordance designs in general and context-dependent use cases. Our results show a medium to low preference for humanlike affordances when the robot's intended use is unspecified. While human likeness positively correlates with perceived warmth and competence, these social perceptions do not significantly drive preferences for humanlike features. Instead, preferences are primarily influenced by robots' intended situational roles, which differ from the stereotypical occupational roles in human society. These results highlight the importance of context-specific adaptive affordance design, which should focus on aligning robot characteristics with contextual expectations of social attributes.**

***Index Terms*—adaptive affordance design, social robots, human-robot interaction (HRI), Stereotype Content Model (SCM), users' preferences**

I. Introduction

In recent years, the concept of 'affordances' has gained considerable traction in the design and development of social robots. Affordances, which refer to the potential actions that an object offers to users based on their perceptions [1]–[4], play a crucial role in shaping how robots interact with objects [5]–[7], as well as how individuals interact with robots [8], [9]. As robots become increasingly integrated into different social environments, it is essential that they are not only functional but also adaptable to diverse and evolving use cases. A critical dimension of this adaptability lies in the perception of the robot's social attributes, particularly its warmth and competence [10], [11]. These attributes not only shape the emotional responses of users, but also influence the overall acceptance and effectiveness of robots in different roles.

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Building on previous work, this paper explores the expanded role of social affordances in influencing human-robot interaction (HRI). The present study extends the prior work [12] by deepening the investigation in two key areas: (1) the relationships between user preferences and social attributes, and (2) the adaptation of the Stereotype Content Model (SCM) for understanding social robot roles. In doing so, we aim to provide a more nuanced understanding of how social affordances can be used to improve the adaptability of robots in both personalized and communal contexts.

The paper begins with a review of the relevant literature on social robots' affordance design and social attributes. Research hypotheses and questions have been formulated in light of these considerations. The paper then presents the experimental materials and methodology, followed by the results, focusing on the relationship between preferences and social attributes and the adaptation of the SCM to the robot role. The results and discussion will integrate the findings from the previous work to enhance the understanding of affordance design.

II. Background and Related Work

Originating from ecology, 'affordance' refers to how users perceive an object and how these perceptions affect their interactions with the object [13]. This relational concept has been adopted by Norman in the design field [1]–[3], including social robot design. It is argued that social robots' looks, sounds and behaviors should be designed appropriately to foster effective perceptions and interactions [9].

Existing research on affordance design tends to focus on anthropomorphism, which examines how a human-like design can appear, such as creating human-like artificial voices that mimic the human tone and speech style (e.g., Google and Microsoft's voice assistants [14], [15]). This strand emphasizes the technical possibilities of achieving human-like qualities. A related line of research explores how to avoid the 'uncanny valley' effect [16], [17]. This concept, introduced by Mori in 1970 [18], suggests that as an object becomes more human-like, it evokes greater affinity to a point where it becomes eerily unsettling due to its high but imperfect resemblance to human beings. To reduce the potentially negative impact of such imperfect resemblance, social robots theoretically require consistency to reflect their functional roles accurately [9].

Empirical studies about consistency focus on single modalities (e.g., coordination within facial features [19], [20]) and on the alignment between different modalities like appearance and voice (e.g., gender consistency between a robot's voice and face [21]). As social robots are used in increasingly different contexts, it is essential to consider the requirements of specific application scenarios and their impact on affordance design. Current research in adaptive social robot design generally focuses on how robots adapt to identify object affordances to meet situational user needs, particularly in manipulation tasks [6] in domestic contexts [5] and in unstructured and hazardous environments [7]. While these studies are valuable, it is equally crucial to explore how users can be supported in better perceiving and understanding a robot's affordances across various contexts. This underscores the importance of the present study on adaptive affordance design.

For robots designed for social use, people's perceptions can be measured through the dimensions of warmth and competence. These social attributes have been well developed and tested in the Stereotype Content Model (SCM) [10], [11], [22], [23]. Warmth reflects the perceived friendliness, kindness and good intentions, while competence denotes the perceived ability, skill and intelligence to deliver on those intentions. The SCM, widely used in sociology, examines stereotypes influencing perceptions. For example, studies about gender stereotypes show that women are often viewed as more communal (warm) and men as more agentic (competent) [24]; occupational stereotypes often lead to segregation based on gender [25], [26]. The SCM has also been applied to study how humans attribute gender stereotypes and social traits to robots based on appearance [27]. The 342 robots' social attributes were examined across 21 perceivable attributes from perceived gender to surface textures and their range of motion [28]. While this approach provides valuable insights, it lacks crucial contextual information, such as the specific roles these robots are intended to fulfil. Intended social roles are key to shaping perceptions [29]. These roles significantly influence how people perceive occupational roles in human society [10], [23], [30]. Understanding how warmth and competence perceptions shift across roles is therefore crucial.

The present study aims to explore the identified gap. The first objective is to understand how people's expectations of social robots' warmth and competence in specific social scenarios influence people's preferences for robots' affordances ('look', 'voice' and 'behavior'). The second objective is to investigate how the SCM applies to social robot roles.

III. Research Hypothesis and Questions

The study hypothesizes that users' preferences for social robots' affordances and those users' expectations of robots' social attributes (e.g., warmth and competence) influence each other. Specifically, preferences for certain affordances will shape users' expectations of the robot's social attributes, while these expectations will, in turn, influence users' preferences for robots' affordances. In addition, the study hypothesizes that when the SCM is applied to robots, users' expectations of robot roles will differ from their perceptions of similar roles in human society. This analysis will lead to reviewing the categorization of robot roles based on warmth and competence. The research questions (RQs) are as follows.

- **RQ1**. How do people's expected social attributes of a social robot influence their preferences for its affordances?
- **RQ2**. How do people's preferences for a social robot's affordances influence their expectations of its social attributes?
- **RQ3**. Do people's expectations of social robot roles' social attributes align with their perceptions of occupational roles in human society according to the SCM?

IV. Experiment Design

An experiment was conducted using a questionnaire that collected participants' demographic information and opinions regarding the affordances of a social robot under different conditions. A 5-point Likert scale was used, with '1' indicating 'strongly disagree' and '5' indicating 'strongly agree'. First, participants answered general preference questions without situational context to establish a baseline (e.g., 'A robot's look should be as humanlike as possible'). Participants were then presented with specific scenarios and asked to indicate their preferences for attributes such as competence ('The robot needs to be competent') and appearance ('The robot needs to have a humanlike look'). The six social scenarios used in this study focused on situational roles in social robot interactions. The scenarios were developed based on the areas where social robots are currently most commonly applied outside research [31]. They include a museum receptionist robot, a leisure companion robot for home use, a private healthcare robot, a personal language tutor robot, a restaurant waiter robot, and a financial advisor robot at a bank.

The study design, the experiment protocol, and the consent forms received approval from our institution's Ethics Committee. The participants were recruited from a university campus. 70 participants completed the online survey, comprising members of the university staff and student body from more than 30 academic or service units. According to the survey results, the majority of subjects were under the age of 34. 35.7% of the participants are aged between 18-24 years old, 40% of them are 25-34 years old, 12.9% of them are 35-44 years old and 11.4% of them are above 45 years old. The gender distribution of participants was relatively balanced, with 57.1% identifying as female, 35.7% as male and 7.1% as non-binary. The majority of the participants (more than 60%) are British. This is followed by Chinese (10%), Indian (4.3%) and other participants with other nationalities, representing a diverse range of national origins. The visualization is provided in the Appendix.

The primary analysis is quantitative. First, it provides an updated overview of participants' general preferences for a robot's affordances, including appearance, voice and behavior. Second, the study compares general and contextual preferences, examining the affordances desired in specific scenarios and the impact of these conditions. Third, the relationship between expected social attributes (warmth and competence) and the affordances of robot roles is analyzed. Finally, social robot roles are mapped onto the SCM, and potential adaptations from human perceptions of social roles are discussed.

V. Results

A. General Preferences of Social Robots' Affordances

When participants do not know what the social robot would be used for, they generally prefer it to have a less humanlike look (mean = 1.93, SD = 0.95), a more humanlike voice (mean = 3.13, SD = 1.17) and less humanlike behavior (mean = 2.34, SD = 1.07). This result confirms the findings of the prior ongoing work [12], indicating that people's preferences are not uniform across different aspects of affordances. The figure is provided in the Appendix.

The Shapiro-Wilk test indicated a violation of normality, so a non-parametric Kruskal-Wallis test was used instead of ANOVA to assess differences between the three groups (look, voice, behavior). A very low p-value ($p < 0.001$) indicates a statistically significant difference in preferences between the three affordances. The epsilon-squared result (ε^2) showed a large effect size (0.525) according to Cohen's benchmarks, explaining 52.5% of the variance. In other words, participants have different preferences for a social robot's look, voice and behavior. However, post-hoc Wilcoxon tests showed no significant pairwise differences between the attributes (all p = 1.0 after Bonferroni correction). In other words, the general preferences for look, voice, and behavior are different overall but not significantly different in a pairwise comparison. Detailed statistical tables can be found in the Appendix.

B. Contextual Preferences of Social Robots' Affordances

The analysis of situational preferences shows that participants' affordance preferences differ across the six social roles provided, as shown in Fig. 1. The results show that participants prefer a more humanlike voice to a more humanlike look across all robot roles. Although participants' preference for a humanlike look increases slightly when they know what the social robots are used for, such preferences are still relatively low (means from $2.06 \sim 2.39$) and consistent across roles (SD from $1.08 \sim 1.23$). In comparison, preferences for humanlike voices have a wider range (means from $3.07 \sim 4.33$) with more divergent opinions (SD from $1.07 \sim 1.37$).

Significant variation in participants' preferences for humanlike features was observed across robot roles. The language teacher role showed the highest preference for a humanlike voice (mean = 4.33, SD = 1.07) but a much lower preference for a humanlike look (mean = 2.09, SD = 1.09). This suggests that vocal interaction is more valued in this role. In contrast, the receptionist role had the lowest preference for a humanlike look (mean = 2.06, SD = 1.08), indicating minimal importance placed on appearances. The home care robot role showed the lowest preference for a humanlike voice (mean = 2.99) but with considerable variation in opinions (SD = 1.37). Similar variability was found for the humanlike look of home care

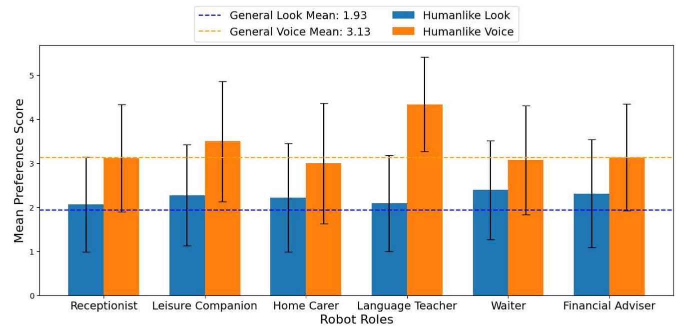

Fig. 1: The graph shows preferences for a social robot's affordances by roles. Group bars represent means. Error bars show standard deviations. Preferences for a humanlike look remain consistent, while human voices are more favored, particularly for language teacher and leisure companion roles.

robots (SD = 1.23), reflecting differing expectations across these roles. A descriptive table with means and standard deviations is provided in the Appendix.

Given the non-normal distribution of data, a Kruskal-Wallis test was used to assess differences. Results showed a significant difference in preferences for a humanlike voice across robot roles ($p < 0.001$) but no significant difference for a humanlike appearance (p = 0.469). This indicates that preferences for a humanlike voice vary by role, while preferences for appearance do not. A medium-to-large effect size was found (ε^2 = 0.126), explaining 12.6% of the variance in voice preferences between roles. Moreover, the post-hoc Wilcoxon signed-rank tests revealed that the language teacher role differs significantly from both general and other situational roles in voice preferences (p-corrected = 0.000). Additionally, voice preferences for the leisure companion robot differ significantly from those for the receptionist (p-corrected = 0.042) and home carer roles (p-corrected = 0.039). Detailed tables are in the Appendix.

C. Relations between Preferences and Social Attributes

Further analysis was conducted to investigate the relationship between social perception (warmth and competence) and people's preferences regarding the affordance of social robots.

1) Descriptive Overview: Fig. 2 provides an overview of the descriptive analysis. Overall, participants have a higher expectation of competence (means from $4.36 \sim 4.79$) and greater consensus (SD from $0.66 \sim 0.89$) than warmth for a social robot (means from $3.36 \sim 4.24$, SD from $0.90 \sim 1.30$). Furthermore, the figure illustrates that these expectations are role-dependent, indicating a potential trade-off between warmth and competence. A descriptive table is provided in the Appendix.

Specifically, the leisure companion role is expected to be the warmest (mean = 4.24) with a small divergence (SD = 0.97). While still seen as competent, it has the lowest expected competence rating among the roles (mean = 4.36) with the greatest divergence (SD = 0.89). Oppositely, the financial advisor robot is expected to be highly competent (mean = 4.79) but less warm (mean = 3.50). Language teacher robot is seen as highly competent (mean = 4.79) with the second

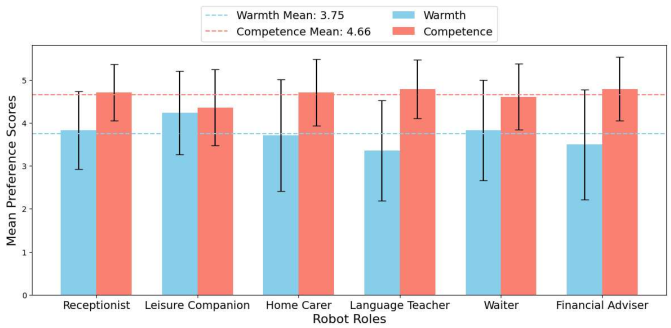

Fig. 2: The figure shows higher expectations for competence for all robot roles. The language teacher is expected to be highly competent but low in warmth, while the receptionist shows the least variation in both attributes.

lowest divergence (SD = 0.68), but it has the lowest warmth ratings (mean = 3.36). Additionally, participants' ratings of the robot's role as a language teacher showed the most marked divergence (1.43) between expectations of a robot's warmth and competence. The role with the smallest divergence is the robot receptionist, with SD = 0.90 for expected warmth and SD = 0.66 for expected competence.

The above overview shows how participants' expectations of a robot's warmth and competence vary significantly across different roles. It also reveals a potential trade-off between warmth and competence, which requires further examination.

2) Inferential Statistical Analysis: To further investigate the differences noted above, a normality test followed by a statistical significance test was performed. The results indicated that the data were not normally distributed. The result of the Kruskal-Wallis test suggests that there is a statistically significant difference between the expected warmth and competence scores across the situations. The effect sizes are small-to-medium for both expected warmth (ε^2 = 0.052) and competence (ε^2 = 0.060). Further, a post-hoc Wilcoxon signed rank test was conducted. Detailed tables are in the Appendix.

Fig. 3 shows effect sizes (Rank Biserial Correlation, RBC) for comparisons between situational roles. RBC values are plotted on the x-axis, with negative values indicating a preference for one role over another and positive values indicating the opposite. Red bars indicate statistically significant comparisons, while blue bars indicate non-significant comparisons. Darker shades reflect larger effect sizes. Out of 15 pairwise comparisons, 10 showed significant differences in warmth expectations, and 7 showed significant differences in competence. In particular, Role 2 (leisure companion) stands out for its higher expected warmth, especially compared to Roles 4 and 6, while it has a lower expected competence than the other roles. These findings suggest that participants have strong, differing expectations of warmth and competence depending on the role.

3) Correlation Analysis: A non-parametric Spearman correlation was conducted to explore the relationship between expected social attributes (warmth and competence) and preferred robot affordances (look and voice). Building on previous research using parametric (Pearson's) correlation [12], the current findings reveal stronger and more nuanced relationships between a robot's humanlike traits and perceptions of warmth and competence. As shown in Fig. 4, warmth is more strongly associated with a humanlike look (r = 0.43), while competence is more strongly associated with a humanlike voice (r = 0.14). Additionally, a significant correlation (r = 0.64) between preferences for humanlike look and voice suggests that participants expect consistency in these traits. The shift from Pearson's sensitivity to linear relationships to Spearman's ability to capture non-linear trends helps to explain the differences in results.

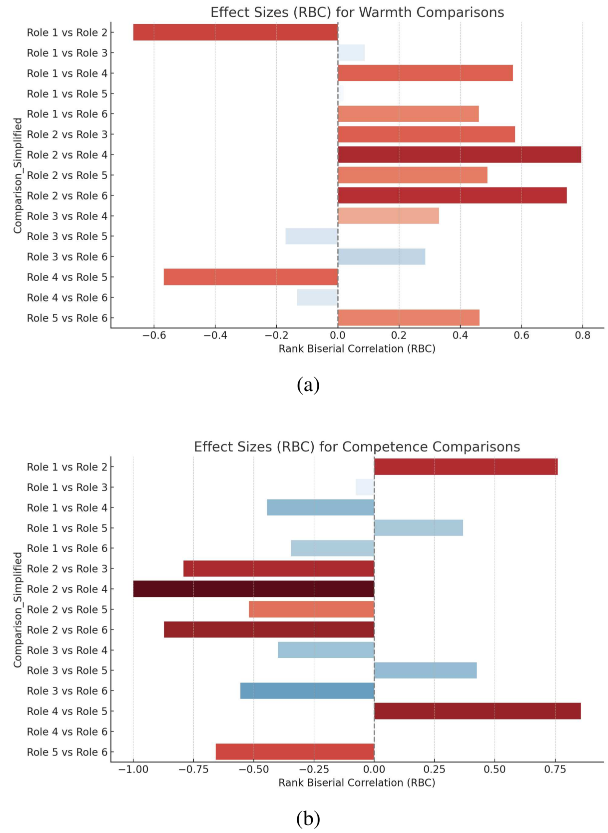

Fig. 3: Effect sizes for comparisons of warmth (a) and competence (b) between pairs of situational roles

Furthermore, mixed-effects linear modeling was conducted to examine the main and interaction effects, including robot roles as a fixed effect to account for role-specific variations. Based on *p* values, both look and voice are significantly positively correlated with warmth and competence. Look has a stronger effect on warmth (Coeff. = 0.498) than competence (Coeff. = 0.229), while voice has smaller effects (warmth: Coeff. = 0.299, competence: Coeff. = 0.134). These results suggest that participants tend to associate warmth and competence more with a robot's humanlike appearance. In addition, the interaction between look and voice was significant for competence but not for warmth, which slightly reduced competence expectations (Coeff. = -0.064). This means that when both look and voice are highly humanlike, competence expectations are slightly lower than when considered separately. While people expect warmth from humanlike robots,

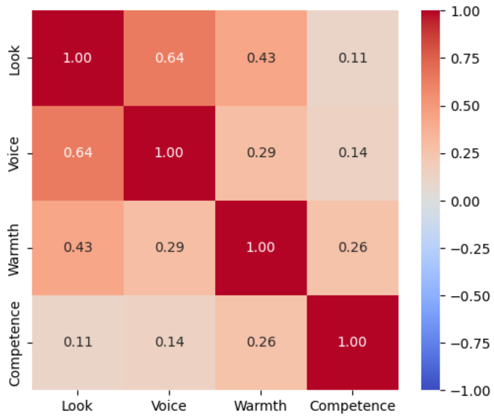

Fig. 4: Spearman correlation heatmap of affordance preferences and social attribute expectations

they may be more skeptical about their competence when both traits are highly humanlike.

Role-specific effects showed that differences were more pronounced for warmth than for competence. Role 2 (leisure companion) increased warmth but significantly decreased competence, suggesting that it was seen as warmer but less competent. Roles 4 (language teacher) and 6 (financial advisor) decreased warmth without affecting competence, indicating they were seen as less warm but equally competent. There was also greater variability in warmth ratings (Participant variance = 0.488) than competence (Participant variance = 0.385), suggesting that individual differences have a greater effect on expectations of warmth. Overall, look and voice are key factors for both warmth and competence, particularly warmth, and participants appear to be more sensitive to their combination when judging competence.

Let's flip the coin to see the other side. If we were to aim for a human look and voice, how would expectations of warmth and competence shape the design? The preference for a humanlike look and voice depends more on the robot's role than on expectations of its competence or warmth. For example, the waiter (Role 5) and the financial advisor (Role 6) are positively correlated with a preference for a humanlike look (Role 5: Coeff. = 0.315, $p = 0.014$; Role 6: Coeff. = 0.380, $p = 0.003$), suggesting participants expect these roles to appear more human. Similarly, Role 4 (language teacher) is strongly associated with a preference for a humanlike voice (Coeff. = 1.381, p = 0.000). The lack of a significant interaction between competence and warmth indicates that participants' preferences for humanlike traits are not influenced by their expectations of social attributes. Detailed tables are in the Appendix.

4) Adapting the Stereotype Content Model for Social Robot Roles: In the Stereotype Content Model (SCM), people are categorized based on perceptions of warmth and competence [10], [11]. Although robots are not humans, this study shows that warmth and competence significantly influence how users perceive robots in different roles. It would be enlightening to explore how robot roles fit into the SCM and any necessary adaptations. Roles are categorized by comparing their mean warmth and competence scores to the group averages (mean warmth: 3.75; mean competence: 4.66). Roles with scores above the average are classified as 'high' and those below as 'low'. The roles are then plotted, with the quadrants indicating high/low combinations of warmth and competence.

In the original Stereotype Content Model (SCM), categories are labeled based on human social stereotypes and emotional responses: 'admiration' for roles perceived as highly warm and competent; 'paternalistic stereotypes' for those perceived as highly warm but less competent; 'envious stereotypes' for roles low in warmth but high in competence; and 'contemptuous stereotypes' for roles low in both warmth and competence. However, these labels may not be appropriate for robots, as it's unclear whether people have the same emotional reactions to robots that fulfill certain roles. Therefore, we propose new category names for robot roles based on their attributes and functions. The new categories and meanings are outlined below, with examples in the Appendix.

- **High Warmth, High Competence:**
  - Original SCM Category: Admiration
  - Proposed Category Name: Hybrid robot
  - Meaning of the New Name: It provides high emotional value and meets functional needs.
- **High Warmth, Low Competence:**
  - Original SCM Category: Paternalistic Stereotypes
  - Proposed Category Name: Companion robot
  - Meaning of the New Name: It provides mainly emotional value. It is not highly functional.
- **Low Warmth, High Competence:**
  - Original SCM Category: Envious Stereotypes
  - Proposed Category Name: Service robot
  - Meaning of the New Name: It provides high functionality. It does not provide much emotional value.
- **Low Warmth, Low Competence:**
  - Original SCM Category: Contemptuous Stereotypes
  - Proposed Category Name: Basic utility robot
  - Meaning of the New Name: It does not provide high emotional or functional values.

After applying the baseline and updated category names, the robot roles were mapped onto the SCM, as shown in Fig. 5. The museum receptionist is expected to be both highly warm (e.g., friendly and approachable) and highly competent in reception tasks. The waiter and home carer roles, although in different quadrants, have similar expectations of warmth and competence. a leisure companion is expected to be warm but less competent, while a financial advisor and a language teacher are seen as highly competent but less warm. Notably, no roles fall into the low warmth, low competence quadrant.

Previous studies suggest that traditional stereotypes are transferred to social robots in human occupational roles [32]. It is worth exploring whether these role expectations reflect social perceptions in human society. Mapping robot roles

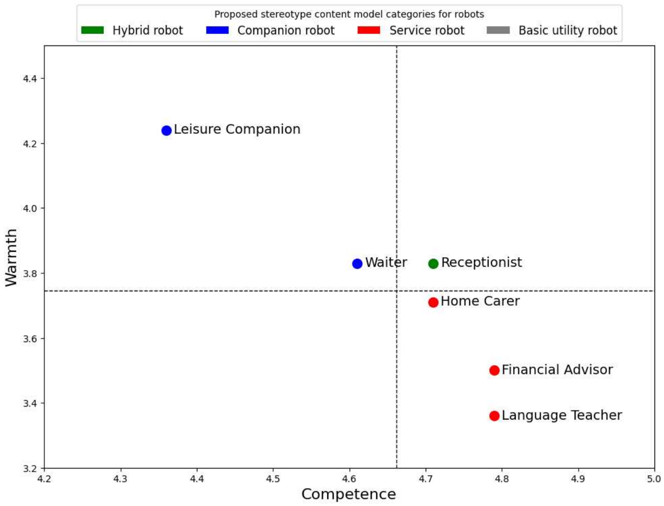

Fig. 5: Mapping robot roles onto the Stereotype Content Model

onto occupational stereotypes [30] reveals differences in how robots and humans are perceived. For example, knowledge-based professionals, such as robotic financial advisers and human accountants, are seen as competent but not warm. Similarly, administrative roles, such as a robot receptionist and a human office assistant, show comparable levels of warmth and competence. However, a robotic home carer is seen as competent but less warm, while a human staff nurse is seen as both competent and warm. A human teacher is perceived as warmer than a language teacher robot, and there is no match for a leisure companion robot. These comparisons show that robots are perceived differently than humans in analogous roles, particularly in emotionally engaging fields such as healthcare and education.

VI. Findings and Discussion

A. General and Contextual Affordance Preferences

Generally speaking, the findings show that humanlike affordances are not necessarily favored when no context is provided. The levels of human likeness across three affordance dimensions are around medium to low. This pattern supports the 'honest signals' hypothesis in the prior theoretical work [9], [33], [34] by confirming that people prefer robots to maintain transparency regarding their non-human identity. In addition, there is a clear trend in preference ratings, with humanlike voice being the most favored (mean = 3.1), followed by behavior (mean = 2.3) and look (mean = 1.9). These general preferences remain the same under situational conditions: people expect situational roles to have more humanlike voices than humanlike looks, with more divergence. This hierarchy suggests that auditory cues are more closely related to human likeness than behavioral and visual attributes.

Moreover, the statistical test showed a significant difference in preferences between the three affordances, with a large effect size. This suggests that users perceive the three dimensions differently. However, no significant differences were found when comparing any two attributes (i.e., behavior vs. look, behavior vs. voice, and look vs. voice). This could mean people do not strongly differentiate between two specific attributes in isolation. It highlights the multifaceted nature of affordance design in human-robot interaction, where multiple affordances collectively contribute to the overall perception of the robot. In other words, the overall affordance design should be consistent and individual aspects can vary. This consistency is also reflected in the moderate-strong correlation (r = 0.64) between humanlike voice and look in situational roles. Such empirical evidence supports that honest signals are helpful if they are correct 'on average' [9], [35].

The questions are: what is the safe boundary of such difference, and how can we measure it? On the one hand, if the difference between a social robot's voice and look is too big, it may generate mismatched perceptual cues, which can trigger an uncanny feeling [17], [20], [36], [37]. On the other hand, according to the analysis of situational roles, the level of the human-likeness of a robot's look and voice has a negative interaction effect on expected competence, although this effect is statistically significant but weak. In other words, if a social robot's look and voice are too humanlike, such affordance would negatively impact the expected competence of that robot. Thus, whilst it is sensible to consider individual components of a social robot's affordance, its overall affordance should also be considered.

B. Social Attributes and Situational Roles

In general, people have higher expectations of competence than of warmth in a situational role. Moreover, such high expectations are also associated with lower variability. This may be because people see social robots as tools and, therefore, value their functionality more. It may also indicate a potential trade-off between warmth and competence, where roles that are expected to be highly competent are not expected to be as warm, or vice versa. For example, the role of language teacher has the highest expected competence (mean = 4.79) and the lowest expected warmth (mean = 3.36). In contrast, the role of leisure companion has the highest expected warmth (mean = 4.24) and the lowest expected competence (mean = 4.36).

In addition, there was greater between-participant variability in expected warmth ratings than in competence ratings overall. To explore potential factors, a Kruskal-Wallis test was conducted to examine the relationship between participants' warmth expectations and their age and gender. The results revealed no statistically significant differences across the age groups (p = 0.92) or between genders (p = 0.21). The variability of expected warmth may stem from other reasons, such as the nature of warmth and competence expectations. While competence tends to be situational and objective, warmth is more subjective, often linked to individual emotional needs. As such, expectations of warmth vary unless the situational role explicitly demands emotional value. For example, warmth expectations for a leisure companion associated with emotional value show the least variability. In contrast, the role of a home carer, a robot primarily described as doing housework and delivering medicine, shows the highest variability in warmth expectations, reflecting the ambiguity of emotional needs.

Regarding the relationship between a social robot's affordances and its expected social attributes, the analysis was conducted from both directions.

a) Affordances' Impact on Expected Social Attributes: The analysis results show that preferences for humanlike looks and voices positively affected expected warmth and competence with statistical significance. In addition, this influence is greater on expected warmth. The finding regarding the perceived warmth is consistent with a prior study about the interaction experiment [38], in which people expected child-like robots to exhibit the highest level of warmth compared to robot-like, adult-like robots.

b) Expected Social Attributes' Impact on Affordances: The preference for a humanlike look and voice is largely unaffected by participants' expectations of robots' competence or warmth. Instead, the affordance preferences are more context-dependent. In other words, the lack of significance for either the main effect or the interaction effect of competence and warmth implies that a robot's expected warmth and competence do not affect how humanlike participants prefer it to look or sound.

C. Illustration of Role-dependent Expectations

The role-specific analysis shows statistical significance across both warmth and competence with a medium effect size. In other words, the users' expectations of situational roles affect how warm or competent a robot is expected to be. The importance of contexts was once again highlighted. Fig. 6 is created to illustrate the relationship between affordances, social attributes and situational roles. Situational roles are in a black box at the top, affordances (look and voice) in green boxes at the bottom left, and social attributes (warmth and competence) in orange boxes at the bottom right. The size of the boxes indicates the importance of the factors. For example, people prefer a more humanlike voice to a more humanlike look and value competence more than warmth. The lines within the boxes indicate the variability of people's opinions. The hatched lines indicate less divergence and more consensus, such as the preferred level of humanlike look and expected level of competence. The zigzag lines indicate more divergence, such as how humanlike a voice is and how warm a robot needs to be. The arrows indicate relationships between factors. The solid lines with arrows indicate statistically significant relationships. The thicker, the more influential.

The graph shows situational roles significantly affect people's voice preferences with a medium-to-large effect size, while they affect people's expected warmth and competence with a small-to-medium effect size. In addition, look and voice significantly affect warmth and competence. The contributions of look are larger than those of voice. Warmth is more affected than competence. Conversely, expectations of warmth and competence had little effect on how humanlike the robot needed to be. The dashed lines with arrows indicate relationships that are not statistically significant but are correlative, as shown between voice and look and between competence and warmth.

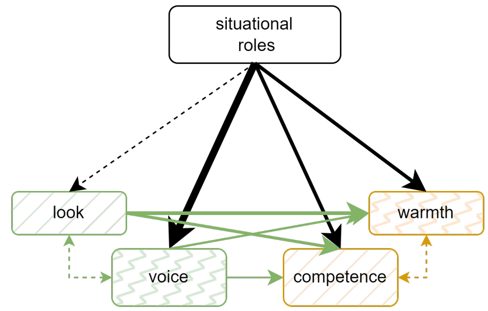

Fig. 6: The figure shows the relationship between affordances (in green), social attributes (in orange) and situational roles (in black).

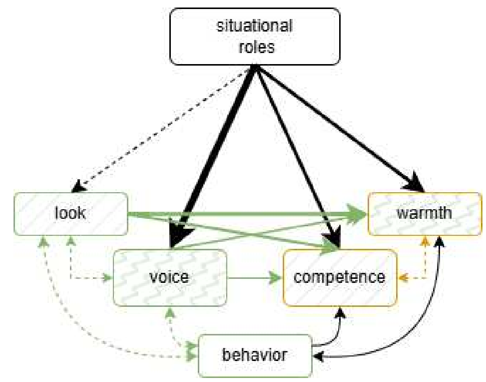

Fig. 7: The figure includes behavior to illustrate the relationship between affordance, social attributes and situational roles. The dashed double-arrow lines on the left represent the correlation between affordances, while the solid double-arrow line on the right shows the interaction between behavioral affordance and warmth. The solid single-arrow line indicates how behavioral affordance influences perceived competence.

Furthermore, behavior is an essential element in affordance design for social robots. Survey results presented in this paper indicate that people do not expect a highly humanlike behavior pattern in a social robot. In addition, behavior is not statistically differentiated from look or voice, but is regarded as an integral aspect of overall affordance coherence. The question thus arises as to how such a preference is linked with warmth and competence. Results from a prior empirical interaction study [38] demonstrate that behavior affordance has a notable influence on perceived warmth and competence. In particular, participants expect robots that appear warmer to behave more warmly. Additionally, variations in behaviors designed for different robot roles have the statistically significant impact on perceived competence and warmth, though with small effect sizes [38]. Combining these findings, we modified Fig. 6 by including a behavior factor situated at the base, as shown in Fig. 7, to enhance understanding of the interaction between behavioral affordances and social attributes.

D. Implication

In light of the above discussion, the findings of this study have the following implications. Human likeness is not the one and only target for the pursuit of designing a social robot's look, voice and behavior. In principle, people would like the robot to be able to show its robot identity via its affordances. In practice, too humanlike look and voice would have a negative effect on people's expectations of a robot's competence. Furthermore, there is no statistical significance between social attributes and the look and voice of a social robot. Therefore, it is worth exploring appropriate affordance designs that do not represent humans. The fundamental principle is to maintain coherence between affordances. It is also worth paying more attention to the design of the voices, as this has a greater influence on the expected warmth and competence.

These findings and discussions highlight the importance of understanding the context in which a social robot is used, as participants' expectations of a robot's voice design, warmth and competence depend heavily on its role. Research [39] shows that service robots' perceived warmth and competence can significantly influence guests' attitudes and intentions to use these robots. Hence, it is essential to design robots with appropriate levels of warmth and competence based on situational needs to enhance robots' acceptance and effectiveness in various roles. In particular, it is essential to prioritize the required competencies in the roles. Despite some roles being categorized as 'low competence' in the SCM mapping, their mean scores are still relatively high (above 4.36 on a 5-point Likert scale). To meet these expectations, the challenge lies in developing adaptable affordance templates for robot types within the SCM. These templates would enable a single robot model to serve in different roles by dynamically adjusting its warmth and competence according to specific situational requirements. This also raises the need to establish common frameworks further to understand use cases.

While the SCM provides a framework to understand people's expectations of robots' warmth and competence, its oversimplified application can negatively impact HRI by reinforcing stereotypes. For example, it could be problematic if robots are designed to embody specific gender traits to show warmth or competence [40], [41], Simply over-relying on the existing SCM may limit the potential for robots to engage with users in a more equitable and inclusive manner [42]. This study shows an example of updating the SCM to reflect human expectations of robots' social attributes in different roles, showing human occupational roles may not directly translate to robot roles. The newly proposed SCM category names offer a framework to guide the design of robots by aligning their social attributes with user expectations for specific tasks.

Warmth scores vary more than competence scores, indicating greater variability in the perception of warmth across roles. It should be noted, however, that the competence and warmth required of a situational role will be influenced by the user's preconceptions. Users will have different expectations depending on a number of factors. Therefore, further research with users is needed to understand what influences their preconceptions and how their preconceptions influence their expectations of robot roles.

E. Limitation

This study has several limitations. First, the sample was drawn from a single university, limiting generalizability to broader populations. Second, the study only examined limited situational roles described by text. Future research could explore a wider range of roles and include images to clarify context and capture the diversity of robotic applications. Third, the reliance on self-reported data via a survey may introduce bias and limit the application to real-life interactions. Results could be validated through emotional metrics and qualitative data gathered in physically or virtually immersive HRI contexts. These future steps could extend and refine the cognitive framework, quantify warmth and competence in affordance design, and provide more robust evidence.

VII. Conclusion

In the context of human-robot interaction, implementing adaptive design is a crucial factor in achieving more acceptable and effective results. A significant number of studies have concentrated on enhancing social robots' capacity to perceive and comprehend their users. Nevertheless, there is a lack of knowledge regarding enhancing users' perceptions and interpretations of a social robot in diverse contextual applications. The study presented here demonstrates the many and varied ways in which individuals' preferences for a social robot's affordance vary depending on the circumstances.

The results show that user preferences for robots' affordance are varied and context-dependent. There is a medium-low level of preference for the humanlike affordances of a social robot when people do not know what a robot would be used for. Although there is a statistically significant difference in the degree of human likeness expected from an individual affordance (look, voice and behavior), these affordances are still treated coherently. Additionally, users' expectations concerning warmth and competence are dynamic and contextual. It is found that a humanlike look and voice positively influence the expected warmth and competence of situational roles. However, neither warmth nor competence expectations significantly affect the preference for a humanlike look or voice. These results highlight the importance of situational roles in adaptive affordance design. It shows that participants' preferences for how the robot sounds and how warm or competent a social robot needs to be are primarily driven by its situational roles. Moreover, the study proposes new categories for robots based on the Stereotype Content Model and points out misalignment between situational robot roles and human occupational roles.

The findings presented in this paper demonstrate that one-sized adaptation does not fit all. Adaptation should be seen as a comprehensive approach to optimizing HRI, including appropriate affordance design, to meet the users' expectations of roles' social attributes in specific use cases and enhance interaction effectiveness. Future studies could be developed to understand the situational robot roles with objective measurements, ideally in physically or virtually immersed scenarios.

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