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Imagination vs. Reality: Investigating the Acceptance and Preferred Anthropomorphism in Service HRI

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ABSTRACT

While the use of robots in public spaces is increasing, still few studies explore the resulting everyday human-robot interactions (HRI). The present study sought to bridge the disparity between real-world interactions and the frequently examined hypothetical interactions. To do so, we investigate the imagined and actual interaction with an ice cream serving robot. In two studies and an exploratory study comparison, we examined user acceptance and preference for the degree of anthropomorphic appearance. Although a typical human service task was taken over by a root, an industrial robot was preferred according to participants' ratings in both studies. Moreover, both studies demonstrated that robot enthusiasm significantly relates to participants' acceptance of the robot for the task. Besides these commonalities, the results showed also that while humans were preferred over robots in the imagined setting, no clear preference was found in the real-life setting. Additional analyses compared the free text answers of the two studies and provided insights into participants' general attitudes toward robots in the workforce. In line with the higher preferences for humans over robots in the imagined setting, considerably more participants mentioned a better customer experience with humans as important in the imagined study compared to the participants who interacted with the robot. The studies strikingly demonstrated that imaginary settings yield similar outcomes to those where participants physically engage with the robot in certain aspects, such as their preference for anthropomorphism. However, this phenomenon does not appear to hold for other facets, such as their favored service agent.

CCS CONCEPTS

•Human-centered computing→Human computer interaction (HCI) →Empirical studies in HCI •Human-centered computing~Human computer interaction (HCI) → HCI design and evaluation methods → Field studies.

KEYWORDS: Human-robot interaction; service robot; anthropomorphism; acceptance; mixed methods; matching hypothesis.

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1 INTRODUCTION

During the COVID-19 pandemic, the use of robots emerged as a solution to balancing service quality while minimizing the risk of infection [1]. While the pandemic may have spurred increased robot adoption within the service sector [1, 2], the level of acceptance gained during this unique period may not be sustained in the long run. This assumption is supported by studies conducted before the pandemic, which emphasized the importance of human interaction and sociability of services in general [3, 4]. For example, Stock and Merkle [5] stated based on semi-structured interviews that user's acceptance of frontline service robots was for the majority based on a comparison to a human employee as a mental reference point. The premise of high sociability and the direct comparison to humans often leads to the belief that humanlike appearance (i.e., anthropomorphism) is a crucial factor for the successful implementation of service robots [6, 7].

According to the *matching hypothesis* [8–10], the (anthropomorphic) appearance of the robot should match the required (social) skills of a task [8] as well as the (social) application domain [10]. For example, in the care sector, Klüber & Onnasch [11] showed that in line with the matching hypothesis, robots with anthropomorphic features are preferred over zoomorphic and technical ones. Importantly, they clearly included not only functional tasks but also tasks with a high degree of sociability and communicational demands in their online research (e.g., welcoming and guiding in care facilities). Most robots implemented in the service domain compromise diverse tasks ranging in their sociability [9, 10], which makes the attainment of generally applicable design recommendations concerning anthropomorphism in this application domain challenging [10, 12]. Furthermore, the majority of studies exploring the matching hypothesis have employed hypothetical vignette studies [8, 10, 11] instead of real interactions with currently deployed robots. Since no real interaction occurred, this could accentuate the reliance on a mental reference point based on comparisons to human employees [5]. This becomes especially intriguing because the robots that have been deployed appear to establish a potential mental reference point that is rather non-anthropomorphic, as most robots that are actually used in the service domain, e.g., for food delivery [3, 13], care [14], cleaning, and security [15] do not resemble humans at all, but are best described as agile boxes [16], [17]. This raises the question of whether the alignment between anthropomorphism and the task is, in fact, a match between anthropomorphism and the possible mental reference point.

In the field of HRI, there is a substantial body of research focusing on expectations and potential application scenarios. However, there is comparatively less exploration of real-world implementations of robots in practical settings [18]. Studies on the perception and acceptance of robots in the social domain often take place via imagined interaction, frequently lacking information about how people interact with robots in the context of their lives and social relationships [18]. The real-world environment in which a robot is implemented provides an opportunity to evaluate unscripted, unaffected interaction with the robot in an everyday setting. "Participants can choose how, when, whether, and why they want to interact with [the] robot" ([19], p.145). While this approach may introduce a self-selection bias among participants, it authentically mirrors the real-world scenarios that often remain underexplored due to the prevalent dominance of artificial settings such as vignette studies. A literature review by Savela, Turja & Oksanen [20] compared studies in which participants were exposed to actual robots with studies in which they encountered robots in a hypothetical setting. They found that attitudes toward robots were significantly more positive when participants were exposed to actual robots. However, the authors themselves stated that their "research has focused on technology that already exists, like automated robotic devices and telepresence robots, instead of emerging technology like autonomous service robots" [20, p.7]. Moreover, as the included studies used a variety of methods and measures, other factors outside the (imagined) nature of the interaction may have played a role.

Looking at other influencing factors that may also affect the task acceptance of the robot while comparing imagined and actual interaction, Andreassen & colleagues [4] mentioned: "customer's technology readiness" (p. 174). Similarly, Li & Wang [21] stated that it is "easier for tech-savvy (vs. average) customers to use a service robot" (p. 7). The results of their research showed that ability –the feeling of being able to successfully interact with a robot– has a significant positive impact on acceptance (more precisely both predictors of the Technology Acceptance Model (TAM) [22], perceived usefulness, and ease of use). Here, we can posit a two-fold effect: first, that individuals who have engaged in actual interactions with the robot have likely already experienced successful interactions, and second, that those who willingly volunteer to interact with a robot are generally more enthusiastic about robotic interactions. Having possible differences in robot enthusiasm between participants in mind, the present studies sought to conduct a more direct comparison between imagined and actual interactions to assess the acceptance of a service robot. Additionally, the studies aimed to explore participants' preferences for (anthropomorphic) robot designs following both interaction scenarios. This was undertaken to ascertain whether not only acceptance but also the favored robot morphology is influenced by the (imagined) exposure to the robot. To study an existing robot that currently operates in the public sphere, a robot known as BonBot which has made its debut in the heart of a city center in Sweden was used. In a café customers can order ice cream with different possible bases, sauces, and toppings via an app and a robot is serving it behind a counter ([23], see Figure 1A). In line with other robots actually implemented in the service domain, BonBot has a rather technical appearance in an anthropomorphic setting [24], as the service robot is replacing a human salesperson with whom customers interact.

Thus, this robot provides a suitable platform to delve into the current research questions, particularly concerning the variations in possible mental reference points for the appearance matching between imagined and actual interactions.

2 STUDY 1 – IMAGINED INTERACTION

In the first study, we explored the imagined scenario using a traditional vignette study without any real interaction with a robot. In accordance with previous research illustrating that a human employee is most commonly used as a mental reference in vignette studies [5], we hypothesized that participants select robots with a medium and high level of anthropomorphism more often as suitable for the task than robots with a low level of anthropomorphism (*hypothesis A1*). Following the above-mentioned findings concerning interindividual differences [4, 21, 22], we hypothesized that the user's acceptance of being served ice cream by a robot (i.e., task acceptance) is higher with a higher level of robot enthusiasm (*hypothesis B1*). Lastly, we also wanted to investigate whether humans or robots are preferred for the task of serving ice cream. Earlier research showed that people expect higher performance from humans than from robots in the food service industry [3] and as mentioned beforehand human employees are utilized as a reference point setting a standard that service robots can hardly reach [5]. Consistent with these findings, we assumed that in an imaginary setting, more participants prefer a human over a robot for the task (*hypothesis C1*). To explore the stated hypotheses, a vignette study was conducted, closely modeled after the real-life experience at the BonBot Ice Cream Cafe.

2.1 Methods

This research complied with the tenets of the Declaration of Helsinki, and the experiment was controlled by a checklist of the local ethics committee. The checklist as well as the preregistration and additional material can be obtained via https://osf.io/uhr2e/.

Participants. A sample size of 64 was targeted to detect a medium effect size of .5 at the standard .05 alpha error probability. In total, 63 participants completed the vignette study (29 women, 34 men, 0 non-binary; M_{age} = 24.65, SD_{age} = 6.24). They were recruited in person on the campus of a Swedish University. None of the participants had heard of the BonBot ice cream store before. All participants filled out the questionnaire on a tablet on the spot. The language of instruction was English. The participants did not receive any monetary reimbursement.

Task & Materials. Participants were given a scenario in which they were asked to imagine themselves walking into an ice cream store where an autonomous robot served ice cream to them. They were also told that they could choose between different flavors and toppings and that the robot would serve them the ice cream at the counter. This description accurately reflected the real experience at the BonBot ice cream cafe. The ABOT (Anthropomorphic roBOT) Database was used to select three robots with different degrees of anthropomorphism (ABOT Database Collection [25]; see Figure 1B). The robot with the lowest Human Likeness Score was Panda (score of 8.48), an industrial robot that intentionally resembles the real ice cream robot BonBot. For the medium level, we chose Aila, a robot with a score of 43.26 but decided to edit the picture to take the lower part with the platform on wheels away since locomotion should not be considered for evaluation in this case. For the highly anthropomorphic variant, we included a picture of Erica in the set, a robot with a Human Likeness Score of 89.6, which is often implemented in receptionist service tasks. Stimuli were presented in randomized order. Both the medium and high score variants showed stereotypically female robot features. According to Perugia and colleagues [26] to date, there are mainly clearly gender-identified robots with medium to highly anthropomorphic designs, while the occurrence of humanoid androgynous robots is lacking completely. Therefore, we decided to stick to the appearance stereotypically assigned to the female gender for the anthropomorphic variants to avoid gender bias by mixing male and female appearances.

Study Design. We conducted a survey where the data was collected from participants without randomly assigning them to a treatment.

Measures. As a control variable, we inquired if participants were familiar with the BonBot robot ice cream store. It was used as an exclusion criterion to ensure their responses were not influenced by prior knowledge of the robot. To assess the acceptance of the robot at the task of serving ice cream, the item "How much do you accept the robot for this task?" was used. Another question was intended to assess the general acceptance of robots in the workforce. There we used the item "How much do you accept robots in general as part of the workforce?". Both items were rated on a 0 % "not at all" to 100 % "completely" sliding scale. Regarding workforce acceptance, we added the open-answer question: "Why did you choose this answer?", for participants to explain their answer in free text form. Preference was assessed by the forced choice single item "Would you prefer to be served by a human or a robot?" with the two possible answers "human" and "robot".

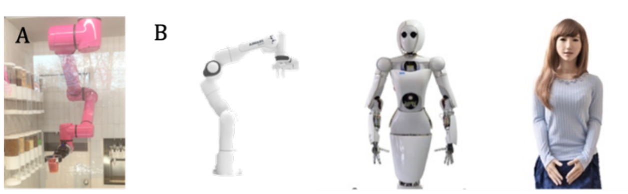

Figure 1: BonBot robot (A) and robot stimuli (B) from left to right: Panda, Aila, and (pictures from ABOT database).

To control for a general attitude towards technology, inspired by the Affinity For Technology (ATI) scale [27] we created a single item for robot enthusiasm: "How excited are you to see robots in real life?". The answer was rated on the same sliding scale ranging from 0 % *not at all* to 100 % *completely.* Lastly, robot fit was assessed by giving a selection of three robot pictures with different levels of anthropomorphism (see Figure 1B) where participants were asked "Which of the following robots would you prefer for the task of serving ice cream?". They could choose one robot by clicking on it. All the questions were created as single items because we aimed to keep the street survey as concise as possible.

Procedure. Participants were handed an iPad to fill out the survey. They started by answering questions on social demographics (age and gender) and were then given the short scenario of the ice cream robot café. The subsequent questionnaire addressed the dependent variables described. The entire procedure lasted approximately 3-4 minutes.

2.2 Results

Control Variables. Gender differences in task acceptance and robot enthusiasm were examined using a Wilcoxon rank sum test. The influence of age on task acceptance and robot enthusiasm was investigated through linear regression. Exploring the influence of gender revealed a significant difference between female and male participants on task acceptance (W = 672, p = .01, r = 0.323). Women tended to report higher acceptance scores (M = 89.38, SD = 19.14) than men (M = 77.35, SD = 23.77). Analyzing gender influence on robot enthusiasm, however, showed no significant difference between female (M = 74.69, SD = 24.8) and male (M = 71.68, SD = 21.76) participants (W = 538.5, p = .53, r = 0.08). The influence of age on task acceptance (t(61) = 0.118, p = .906, R2 = 0.000) and robot enthusiasm (t(61) = 0.583, p = .562, R2 = 0.006) turned both out to be not statistically significant.

Dependent Variables. Dependent measures were analyzed using χ2-tests for robot fit choice and human vs. robot preference. A linear regression tested the hypothesis of higher task acceptance with increased robot enthusiasm. Violations of parametric test assumptions led to the use of Wilcoxon rank sum tests for non-normal distributions. Checking for hypothesis A1, results on the χ^2-test regarding the robot fit showed a statistically significant difference between the frequencies of the selected options ($\chi^2(2, N = 63) = 46.57, p = .001, W = .86$). However, Bonferroni-corrected pair-wise post-hoc comparisons revealed that the differences were not in the expected direction. Significantly more participants chose a robot with a low level of anthropomorphism (Panda; 46 participants) than with a medium (Aila; 13 participants) ($p < .001$) or high level (Erica; 4 participants) ($p < .001$).

Looking at the task acceptance on a scale of 0 to 100 %, the mean value $M = 82.89$ was descriptively quite high. To check if task acceptance was higher with a higher level of robot enthusiasm (hypothesis B1), we performed a linear regression. Results showed that the regression model was significant ($F(1, 61) = 6.022, p = .017$) and that there was a significant positive influence of robot enthusiasm on task acceptance $t(61) = 2.454, p = .017, R^2 = 0.09$). Controlling for gender (as a significant difference was revealed between female and male participants), we included the variable in the regression model. Results revealed that robot enthusiasm still related significantly to task acceptance; $t(60) = 2.379, p = .021, R^2 = 0.15$).

A ceiling effect of task acceptance scores is visible in the data. 26 out of 63 participants indicated a task acceptance of 100%. Looking at the distribution of robot enthusiasm, it became apparent that the ceiling effect was not quite as pronounced as in the case of task acceptance, but that a similar pattern was nevertheless discernible.

The average score was M = 73.06 and 23.8% of the respondents indicated with the highest score that they were completely excited about the robot. Regarding human/ robot preferences, results revealed a statistically significant difference between the two options human and robot; $(\chi^2(1, N = 63) = 11.571, p = .001, W = .43)$. As assumed in hypothesis C1, more participants chose to be served by a human (45) rather than a robot (18).

2.3 Discussion

The first study aimed to investigate in an imaginary setting how a robot in a service domain like an ice cream café is accepted, how anthropomorphic the robot is expected to look, and whether a human or a robot is preferred for serving ice cream. The results of the study interestingly did not support the hypothesis that more participants would select robots with a medium and high level of anthropomorphism than with a low level of anthropomorphism as suitable for the task. In contrast to the matching hypothesis [9, 10, 11], the most selected robot for the task of serving ice cream was the industrial arm with the lowest anthropomorphic level. This can be attributed to various factors on the part of the human, robot, or task scenario. For example, due to the engineering orientation of the Swedish University knowledge of robotics is assumingly high among the participants as well as their interest in robots, which was reflected in the high robot enthusiasm scores. Their specific backgrounds could have led them to see robots as more rational than people who are not as tech-savvy, even in human tasks like serving ice cream [28]. Moreover, industrial robots like Panda are more common in the engineering field. Highly anthropomorphic robots are very rare and the chances that the respondents have ever seen one in real life are low [29]. It is also possible that they focused on feasibility. This claim is consistent with recent research that found that subjects tended to have higher trust in a technically designed robot than in an anthropomorphic robot [30]. In addition, the highly anthropomorphic variant could have produced an *uncanny valley effect* [31]. To eliminate this effect and possible gender effects, future studies could use robots at the lower end of the human likeness scale, up to a score of around 65 [32]. Nevertheless, despite considering all these potential influencing factors, the most noteworthy explanation lies in the inherent lack of sociability within the task itself [9, 10, 11], which possibly rendered the industrial robot an ideal fit for a predominantly industrial pick-and-place task. In particular, Kwak [34] compared robots with human and industrial appearance in a study, where the industrial appearance of the latter maximized the functions of the robot. The result was that while participants rated the humanoid robot as more sociable, they were more satisfied with the service provided by the industrial robot. Thus, for this specific task of "assembling" an ice cream, the design principle of "form follows function" could lead to a preference for the industrial robot.

Even though the participants were generally enthusiastic about robots, the hypothesis that task acceptance is higher with higher robot enthusiasm was still supported by the findings in this study. There seems to be a relationship that suggests that the more enthusiastic people are about robots in general [17], the more accepting they are of them for the task. The reduction to one single item must be named as a methodical limitation and needs to be validated further. However, the strong link to task acceptance offers a promising first clue for future use. Particularly striking was the clear ceiling effect on task acceptance. This, again, could be due to the tech-savvy sample. Interestingly, there was a gender difference in task acceptance, with women giving higher ratings than men, but no difference in robot enthusiasm. This is remarkable, as men are often stereotypically associated with greater enthusiasm for technology in general than women. Future research should explore whether robots constitute a unique technology that is not as strongly affected by stereotypical enthusiasm disparities.

Moreover, the results of this research provide supporting evidence that human service is preferred as hypothesized. This is in line with previously stated research [3, 4]. Stock and Merkle [5] described that human employees set a gold standard that service robots can hardly reach. This assumption could be reinforced by the fact that the robot has only been imagined, which might have led to the human comparison as a mental reference point.

In conclusion, we found that an industrial robot was preferred for the task, higher enthusiasm goes hand in hand with greater task acceptance, and humans were favored for ice cream service. Despite limitations in the tech-savvy sample and short survey, results offer multiple theoretical and practical insights as well as avenues for future research, which should broaden findings with a more representative sample, addressing potential bias. Most importantly, whether results hold beyond imagined interactions was investigated in the subsequent real-life study.

3 STUDY 2 – REALITY

Having a service robot in a public café allows researchers to examine the acceptance of an industrial robot in an everyday context. Reversed to the original hypothesis and mirroring the actual results of the first study, we hypothesized that more participants at the ice cream store select robots with a low level of anthropomorphism than with a medium and high level of anthropomorphism (*hypothesis A2*). Importantly, this assumption was stated independent of the results of the first study based on the overriding of possible expectations by the actual interaction of an industrial robot [35]. In line with the first study, we assumed that task acceptance is higher with higher levels of robot enthusiasm (*hypothesis B2*). Moreover, the preference for either robots or humans serving ice cream was investigated. In a study by Romanjuk [36] the author compared preferences for human versus robot delivery in Tallinn where Starship Technologies have recently been implementing autonomous robot delivery services. In a survey participants slightly preferred robot delivery over a human courier (55 %). Participants could also comment on their decision and they mentioned among others that it is safer, "less harmful for the environment" and "more convenient" to be delivered by a robot but that robots are still "not as well-developed" and "make lots of errors" ([36], p. 31-32). Due to these findings, we suspected that more participants prefer a robot over a human for the task after they have experienced the interaction (*hypothesis C2*). To create the most comparable situation, the procedure closely mirrored that of study one. The goal was to introduce differences solely in the experience of the interaction, recognizing that achieving perfect control in a field study is inherently challenging (if not impossible).

3.1 Methods

Participants. Again, a sample size of 64 was targeted. In total, 65 participants (32 women, 31 men, and 2 non-binary individuals; Mage = 37.46, SD = 11.27) completed the study. They were recruited in person in front of the BonBot ice cream robot café in Sweden after having interacted with the robot. All participants filled out the same questionnaire as in the first study on a tablet and did not receive any monetary reimbursement.

Differences to Study 1. Study 2 was very similar in design to the first study, with only a few differences. First, the participant's task in the second study was to evaluate their experience with the ice cream robot after they had interacted with it and successfully ordered ice cream. Second, to control for the novelty effect, we asked participants if this was their first time visiting the robot ice cream cafe. Again, we used two single items to assess the task and workforce acceptance, respectively. To assess the acceptance of the robot at the task of serving ice cream, we therefore added "You have just ordered ice cream at the Bonbot store." before the same item from the first study was used. Workforce acceptance, the open-answer question, preference, robot enthusiasm, and robot fit were assessed via the same items as in the first study.

3.2 Results

Control Variables. Exploring the influence of gender revealed no significant difference between female (M = 95.09, SD = 14.94) and male (M = 94.03, SD = 16.85) participants on task acceptance (W = 526.5, p = .51, r = 0.083). The sample incorporated two non-binary individuals, which were excluded from the analysis concerning gender differences due to the small group size. Analyzing gender influence on robot enthusiasm also showed no significant difference (W = 484, p = .86, r = 0.022) between women (M = 82.97, SD = 23.72) and men (M = 83.52, SD = 21.54). The influence of age on task acceptance (t(63) = -0.705, p = .483, R2 = 0.008) and robot enthusiasm (t(63) = 0.351, p = .727, R2 = 0.002) were not statistically significant. 51 out of 65 participants (= 78.5 %) indicated that they visited the BonBot ice cream store for the first time. Even though task acceptance scores were descriptively slightly higher on average for people who visited the store for the first time (M = 95.39, SD = 15.24) than for people who had been there more often (M = 91.14, SD = 17.1), this difference was not statistically significant (W = 304, p = .195, r = 0.161). However, looking at robot enthusiasm scores in both groups revealed a possible novelty effect: Participants who visited the ice cream store for the first time (M = 87.29, SD = 19.83) had significantly higher robot enthusiasm (W = 166, p = .001, r = 0.398) than participants who had been there before (M = 68.36, SD = 25.39).

Dependent Variables. Checking for hypothesis A2 by analyzing the robot fit via a χ^2-test showed a statistically significant difference between the frequencies of the selected options ($\chi^2(2, N = 65) = 44.89, p = .001, W = 0.83$). Bonfer-roni-corrected pairwise post-hoc comparisons revealed that the differences appeared to be in the expected direction. Significantly more participants chose Panda (46 participants), the industrial robot with a low level of anthropomorphism than Aila (16 participants) with a medium ($p < .001$), or Erica (3 participants) with a high level ($p < .001$). By taking a closer look at the variable task acceptance, which was assessed on a scale of 0 to 100%, a clear ceiling effect was revealed. The mean value was very high with M = 94.48. We still wanted to investigate whether task acceptance is higher with a higher level of robot enthusiasm (hypothesis B2), so we ran a linear regression. Results showed that the regression model was significant ($F(1, 63) = 12.45, p = .001$) and that there was a significant positive influence of robot enthusiasm on task acceptance ($t(63) = 3.529, p = .001, R^2 = 0.165$). The ceiling effect of task acceptance scores is visible in the data. 54 out of 65 participants indicated a task acceptance of 100%. This corresponds to a proportion of 83.1% of all participants who completely accept the robot for the task of serving ice cream. Looking at the distribution of robot enthusiasm a similar pattern becomes apparent. The average score was M = 83.22 and 46.15% of the respondents indicated with the highest score that they were completely excited about the robot. Regarding the human vs. robot preferences, results showed no statistically significant difference between the two options ($\chi^2(1, N = 65) = 0.754, p = .385, W = 0.11$), contrary to our expectation in hypothesis C2. Nevertheless, descriptively more participants chose a robot (36) over a human (29).

3.3 Discussion

The aim of the second study was to investigate our research questions in a real-life setting. In line with our hypothesis, the most selected robot had a low level of anthropomorphism and resembled the ice cream robot BonBot. As previously noted, this result may not necessarily contradict the matching hypothesis [9, 10, 11], as the task's low sociability aligns with the less anthropomorphic appearance of the robot. In other settings where the social service factor is more important, for example, if you need advice when buying a present in a store, this might be different. Robots that perform service jobs requiring more extensive social interaction with humans (like a receptionist) might preferred to have higher anthropomorphic characteristics not only in imagined [9, 10] but also in actual interaction. This issue could be a good starting point for future research to explore at what level of interaction or consulting expenses people would wish for a robot with a higher degree of anthropomorphism. Although the present results clearly support our first hypothesis, it is appropriate to recognize two potential limitations. First, the one-to-one survey method directly in front of the store may have led to the participants feeling obliged to confirm the robot used in the cafe, so they may have answered in a socially desirable way [37, 38]. Second, as described in the first study the highest anthropomorphic variant Erica could have been perceived as eerie due to the uncanny valley effect [31], which would explain why it was again chosen the least often.

Similar to the first study, the task acceptance was very high, and a clear ceiling effect was visible. This could be due to a self-selection bias [39]. Respondents of the survey were presumably already interested in the robot ice cream café when visiting the store. Besides, having already been a customer in the store and having used the robot's service does already confirm acceptance of the service. Assessing a low task acceptance after the voluntary use of the robot would lead to cognitive dissonance [40], which is avoided. The selective sample most likely also explains the ceiling effect of robot enthusiasm. Almost every second respondent was very excited about seeing robots in real life. The experience of interacting with the robot itself could have also added to the high scores of task acceptance and robot enthusiasm. Again, as assumed, a higher robot enthusiasm was associated with a higher task acceptance. Moreover, the results showed no clear preference for human or robot service although a tendency to choose robots slightly prevailed. However, the fact that it has failed to become significant could indicate a rather indifferent attitude because the focus is on the result and since the interaction is minimal, it does not really matter who serves the customer. Moreover, the robot seems kind of inaccessible. It is located in its own area behind glass, which creates little opportunity to engage with it anyway. Nevertheless, the ambiguous preference result raises the question of whether even this specifically robot-enthusiastic sample has conscientious objections to the use of robots. To investigate this question, we looked at workforce acceptance and examined the open responses in more detail (see section *4.3 Evaluation of Workforce Acceptance*).

In terms of future research, it would be useful to extend the current findings by conducting a very similar field study but changing to a within-design, where participants are given the same questionnaire before and after the interaction. In this way, changes in ratings could be directly attributed to the interaction with the robot itself. This would help explain the impact of direct experience with a robot. Moreover, in the selection option for robot fit, the gradation between industrial and medium anthropomorphic variants seemed very high. In future studies, the selection could be more fine-grained with an intermediate level in each case, i.e., multiple selection options, in order to achieve a better fit and to rule out that higher anthropomorphic variants are generally not selected, as some examples can have an uncanny effect [31]. In order to make even more substantiated claims about the influence of direct interaction on acceptance, a further study could investigate the interaction with all the robot options. Such a study in a similarly real-life setting would be difficult to realize, but a lab study with real interaction could be a good complement to our findings.

Although the generality of the current results must be established by future research, the present study has provided clear support for preference for an industrial robot in a service task with low sociability, illustrating that human service task might not always best replaced by an anthropomorphic robot. Not only was the industrial robot by far the most selected option but the task acceptance showed a very clear ceiling effect, which again demonstrates how approved the robot was. Furthermore, the relation of robot enthusiasm and acceptance once again confirmed that interest in technology is known to predict technology acceptance, which is in line with previous research [28, 41]. The results highlight the significance of considering both human-related and robot-related factors.

4 EXPLORATORY COMPARISON

Comparing studies in which participants interacted with robots in hypothetical setting versus real life revealed that attitudes toward the robot were significantly more positive when exposed to actual robots [20]. Similarly, Casas & colleagues [33] found that actual interaction with a robot can lead to a more positive perception of it. The current studies offer the opportunity to investigate possible differences between imagined and experienced interaction for the same task, even though the participants might not be perfectly comparable. To start, we outline the differences among the studies. The first study was largely surveyed among students in the environment of a technically oriented university. The average age of the participants was about 25 with a relatively small standard deviation. The second study was conducted in front of an ice cream café, which was frequented by a public audience of various ages. The average age here was 37.5 and the standard deviation was higher than in the other study. Performing a Welch two-sample t-test confirmed that mean age scores differ significantly in both study samples ($t(100.54) = -7.99$, $p = .000$, $d = 1.4$). Due to the differences in age and general selection of the samples, comparisons are merely exploratory. However, it's important to point out that these differences align with the typical participant selection seen in vignettes (i.e., students) versus field studies (i.e., the general public). Therefore, the approach to compare Study 1 and Study 2 can provide valuable insights and knowledge to compare the studies and examine similarities and differences. In the first part, the studies will be exploratory compared on a quantitative level. In the second part, the item workforce acceptance and the additional open-ended question which were not included in the hypotheses will be evaluated and analyzed qualitatively (see Figure 2). The fear that people will lose their jobs due to robots that replace them is a widespread concern [42]. Therefore, we were interested if this also applies to a service robot in an ice cream store.

4.1 Quantitative comparison

For the first hypothesis, a quite similar distribution was found in both studies concerning the preferred robot's anthropomorphism. In both studies the majority (46 participants in each study) preferred the low anthropomorphic robot, Panda. A χ^2-test confirmed that the distribution did not differ in the two studies ($\chi^2(2, N = 128) = 0.422, p = .81, W = 0.057$). Looking at the hypothesis that dealt with human vs. robot preference, we found a significant association between the type of interaction with the robot (imagined vs. experienced) and preference ($\chi^2(2, N = 128) = 8.363, p = .004, W = 0.27$). Even though being served by a robot is descriptively chosen more often after an experienced interaction in study 2 (36 times out of 65) than after imagined interaction in study 1 (18 out of 63), this difference failed to reach significance ($p = 0.086$). Analogous, humans were slightly more often chosen in study 1 (45 times, which corresponds to 71.4%) than in study 2 (29, which corresponds to 44.6% of responses), but Bonferroni-corrected pairwise post-hoc comparisons showed that the difference was not significant ($p = .377$). We also compared differences between both studies in terms of task acceptance and robot enthusiasm. Due to the ceiling effect of task acceptance and the fact that the variable was not normally distributed, we calculated a Wilcoxon rank sum test.

The results showed that task acceptance after real interaction ($M = 94.48$, $SD = 15.62$, $Median = 100$) was significantly higher ($W = 1215.5$, $p = .000$, $r = 0.403$) than after imagined interaction ($M = 82.89$, $SD = 22.42$, $Median = 88$). Another Wilcoxon rank sum test indicated that robot enthusiasm in the experienced interaction group ($M = 83.22$, $SD = 22.35$, $Median = 98$) was significantly higher ($W = 1480.5$,

p = 0.006, r = 0.244) than in the imagined interaction group (M = 73.06, SD = 23.07, $Median$ = 74).
Workforce acceptance was assessed in both studies, but group mean values for study 1 (M = 75.98, SD = 21.37) and study 2 (M = 78.72, SD = 21.46) did not differ (W = 1852, p = .344, r = 0.084).

4.2 Qualitative comparison

In a further exploratory approach, we coded the free-form text answers to the question "Why did you choose this answer?" referring to their rating of workforce acceptance by categorizing it into different themes related to pro-robot or pro-human attitudes. In total, we were able to analyze 122 different text entries, in which 183 segments were coded. We started by scanning the text sources for arguments pro and contra robots in the workforce. The chosen method was based on content analysis [43] but with an inductive approach, meaning that new categories could be added during the process of coding. In the end, 5 broad categories emerged for a pro-human and pro-robot side each and one rather neutral or in-between category. All answers were allocated to those categories and sometimes answers were broken down into different segments and coded with more than one category. Overall, about 28% of the coded segments fell into the superordinate pro-human category, while about 59% belonged to pro-robot. The remainder of 13% was assigned to the in-between category. The five subcategories of pro-human and pro-robot and the in-between category with examples and their share of all coded segments are presented in a table available on additional material in the Open Science Framework.
The most frequently mentioned subcategory of pro-human was *Better customer experience*. The desire for human contact was captured here, as well as better service, since people can respond to customers individually. Participants mentioned that they "still love a human smile" or that "human is more personal". Someone also commented that they prefer humans "in a shop, where I need the advice to choose a product or in a restaurant, where I like to interact with the waiter and talk about e.g. the vine selection". The second most common category of pro-human was *Humans outperform robots*. Some respondents argued that robots sometimes lack the capabilities that humans have and that humans are still needed to operate robots and prevent mistakes. The next category was *Robots take jobs away*. This category had two components. First, all responses that expressed a fear of losing jobs to robots were included, and second, comments that argued that as long as it is possible and safe, humans should remain the first choice for a job even if robots were capable all the same. *Preference for humans in some fields* was a category that summarized comments related to the particular suitability of humans in the service and medical fields. "I prefer human interaction in for instance an ice cream shop" is one example stated by a participant. The last category *Negative attitude towards robots* included all comments that focused on negative connotations with robots, for example, lack of trust, not seeing a need for robots, or seeing robots as ethically questionable for some tasks.
On the pro-robot side, the category with the most coded segments was *Robots as good workers*. It included all arguments about robots being more productive (more efficient, effective, and accurate), helpful, and making fewer mistakes. Example comments here were: "Robots can be more efficient and precise", "they provide efficiency and [...] reduce costs in the long run" and "they don't have to rest". The category *Robots minimize labor pain* was in second place. Comments that fell into this category related to the topic that robots take over the burden of heavy, dangerous, and tedious but also repetitive, monotonous, and simple work and increase safety. As a result, robots leave humans with more creative or generally more attractive jobs. *Robots are the future* described as the category, in which all answers revolve around robots meaning progress. For example, one respondent stated: "I think [robots are] an important part of adjusting to the future". Answers that were coded under the category of *General improvement with robots* meant that robots can

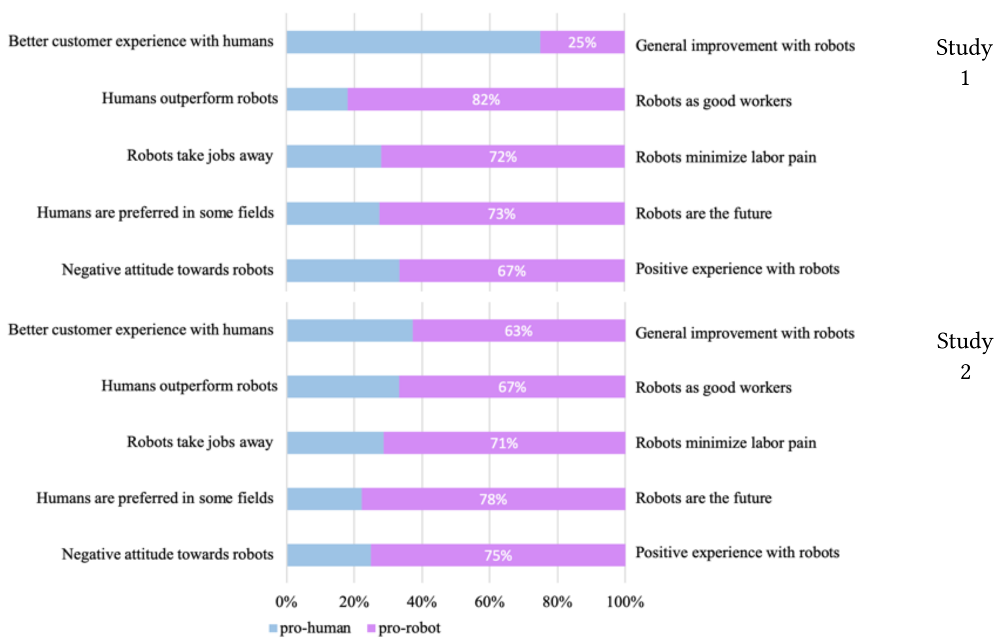

Figure 2: Proportion of coded segments within each scale of matched categories for Study 1

improve society, wealth, and life and bring more convenience to human life. The last category *Positive experience with robots* refers to trust and knowledge of robots and affinity for robots which was expressed by saying that they love the interaction with robots or describing them as fun, cool, or awesome. Trying to divide the in-between category more finely resulted in the subcategories *Acceptance with limitations,* meaning that people accept robots under certain conditions (deployment in the industry only or safe for the environment) and *Other.*

The values of the categories pro-human and pro-robot seemed to be opposites of a common scale. Therefore, we tried to match the categories, resulting in five bipolar quasi-scales. We visualized the proportion of answers within each scale. In Figure 2 the distribution of coded segments within the five different scales is presented for both studies. For study 1, it is noticeable that the shares of segments that fall into the pro-robot category clearly predominate for four of the five scales. Only in the category *Better customer experience with humans versus General improvement with robots* is there a higher proportion on the pro-human side. Looking at the distribution for study 2 the distribution for all scales is predominantly on the pro-robot side. This is particularly pronounced for the categories *Humans are preferred in some fields versus Robots are the future* and *Negative attitude towards robots versus Positive experience with robot.*

4.3 Discussion

The exploratory comparison aimed to gain insights into the expectation vs. reality of an industrial robot's fit and task acceptance in a human service area, as well as the perception of robots as part of the workforce. It is important to note that the populations of the studies were not comparable due to their different age and enthusiasm toward robots. Hence, caution must be exercised in concluding based on the exploratory comparisons. In line with earlier research [18, 20] mean scores for acceptance and robot enthusiasm were higher in the second study than in the first. However, due to real-life conditions, biases such as self-selection [39] and avoidance of cognitive dissonance [40] after using the service may have occurred. In the second study, task acceptance was rated higher than workforce acceptance, indicating that people are excited about this specific robot after interacting with it but are still hesitant to generalize their acceptance to all robots in the workforce.

When it comes to the distribution of robot selection with different levels of anthropomorphism the findings indicate that the setting made no difference. Regardless of whether participants imagined or experienced the scenario with the service robot, they preferred the industrial design. This suggests that the setting is not a significant factor in this regard; instead, reasons discussed previously, such as stimuli selection and the appropriateness of an industrial robot for low-service tasks [10, 12], might play a more important role. It is also very likely that the participants opted for the industrial robot because they had previously interacted with the visually very similar BonBot. However, as the preference holds true for both studies there also seems to be a general preference for technical robots for this task independently of the actually implemented robot.

Even though there was no clear difference in the preference between humans and robots, robots were descriptively chosen more often in the second study and humans vice versa in the first study. This could either be attributed to the positive experience of interacting with the robot or the self-selection bias where participants might have already had a slight robot preference before. Nonetheless, pro-robot comments were predominant in both studies, emphasizing the efficiency and suitability of robots for various tasks, especially those that are dangerous, strenuous, or monotonous for humans. On the other hand, pro-human comments highlighted the importance of better customer experiences with humans and the need for humans to be able to take over robotic tasks when necessary. Interestingly, in the first study, the only scale where pro-human comments predominated was *Better customer experience with humans versus General improvement with robots.* This is consistent with the preference for human service in the first study. Here, participants had been thinking of specific situations in which they appreciated and sometimes even required human service, for example when receiving advice in a shop. Results from the content analysis made it clear that human contact as social interaction is highly valued and cannot yet be replaced by robots. The responses from Study 2, on the other hand, indicate that the customer experience was compelling for most customers and that they were satisfied with the robotic service. All in all, despite high workforce acceptance, statements indicate that humans and robots should each be assigned tasks according to their capabilities, that robots should only be used when it makes sense, and that the importance of human interaction should not be underestimated.

5 CONCLUSION

Although the transferability of the results to other applications needs to be investigated by further research, the present two studies have provided clear support for the use of an industrial robot in a service domain with minimal required sociability. Although a typical human service task was taken over by a robot, the type of interaction with the robot was not social in nature and an industrial robot proved to be a suitable match [9, 10, 11]. Moreover, a less anthropomorphic robot does not raise false expectations and is less likely to be compared on the same level as a human being. In both studies, it could be demonstrated that robot enthusiasm has a significant positive influence on the task acceptance of the robot, which is well in line with earlier research [17, 21, 28]. Moreover, as hypothesized, humans were preferred over robots in an imaginary setting, whereas no clear preference was found in the real-life setting, which might be related to different mental reference points. Exploratory analysis of open-ended responses on workforce acceptance showed a prevalence of pro-robot viewpoints. Participants generally portrayed robots as supportive, alleviating humans from undesirable tasks, and acknowledged their importance in today's productivity-driven world. Though pro-human responses existed, they underscored that humans couldn't be fully replaced by robots. While robots serving ice cream were viewed as fun additions rather than necessities, the optimal utilization of robots was emphasized, capitalizing on their strengths. As a study that truly addresses human-robot interaction in the field, it gives insights into the acceptance of autonomous service robots in the context of real and everyday life, which should be followed up and deepened by a series of further studies.

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