Effects of a Co-Located Robot and Anthropomorphism on Human Motivation and Emotion across Personality and Gender

Lawrence H. Kim[1], Veronika Domova[2], Yuqi Yao[3], and Pablo E. Paredes[4]

Abstract— **In this paper, we study how a co-located robot affects human motivation and emotion. In particular, we examine the role of the co-located robot's anthropomorphism, as well as the effects of the human's personality and gender. To study this, we conducted an online experiment, where 182 participants completed a repetitive task, either easy or hard, in one of the four conditions: in the presence of a non-anthropomorphic robot, an anthropomorphic robot, another human, or alone. For each condition, we analyzed the number of repetitions and the total time users spent, which we treated as the proxy of their motivation, as well as their self-reported emotional states. The study results suggest that the presence of a non-anthropomorphic robot has the potential to lead to a higher level of motivation and a more desirable affective state for users than the presence of an anthropomorphic robot or another human, especially for introverts and female users during difficult tasks.**

I. Introduction

In recent Human-Robot Interaction (HRI) research, utilizing anthropomorphic robots as coaches, instructors, and motivational agents has become increasingly prevalent in various applications including education [1] and domestic services [2]. Robots developed for these purposes mostly utilize anthropomorphic designs to imitate human's appearances and behaviors [3], [4], [5], [6].

While the robot's human-like appearance and behavior are important for accepting the robot as a social agent [7], anthropomorphic features in commercially deployed robots are not always available. One underlying reason is that anthropomorphic features require additional costs while are not mandatory for performing the assigned tasks such as vacuuming. Furthermore, in some contexts, anthropomorphic robot designs are not appropriate because they can mediate negative effects on the interaction experience by inducing false expectations to users [8]. For these reasons, HRI community will benefit to know whether the anthropomorphism is an essential feature in motivational agents and to which extent the motivational robot should be anthropomorphic. To our knowledge, no existing study employed non-anthropomorphic robots as motivational agents or investigated how the anthropomorphism of the agent influences the motivation of the user.

This work was supported by Stanford Transforming Learning Accelerator. Contributions from L.K. were made while in transition from Stanford University to Simon Fraser University.

[1] School of Computing Science, Simon Fraser University lawkim@stanford.edu
[2] Department of Mechanical Engineering, Stanford University
[3] School of Education, Stanford University
[4] Department of Psychiatry, School of Medicine, Stanford University

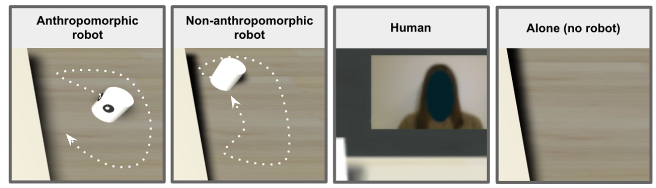

Fig. 1. Different presence conditions presented to participants to test the effects of a co-located robot and its anthropomorphism.

In this study, we investigate if and what role the anthropomorphism of a co-located robot plays in humans' motivation. In particular, we are interested to capture the effects of a subtle increase in the robot's anthropomorphism, via inclusion of eyes, on the user's motivation. As demographics of users, such as personality and gender, often heavily impact HRI [9], [10], [11], we also investigate if and how the human's personality and gender will mediate the effects of a co-located robot. To address these research questions, we rely on existing research on motivation, motivational robots, effects of personality and gender in HRI, and social facilitation.

We conducted an experiment where 182 participants performed a repetitive task within a virtual environment. In particular, we measured the user's motivation and emotion under binary levels of anthropomorphism (non-anthropomorphic vs. anthropomorphic) and compared them with two baseline conditions: alone and human presence. To capture motivation and emotion, we used behavioral and cognitive measures. In addition, we analyzed the effects of the extroversion traits of the participants' personality and their gender.

Our results demonstrate the benefits of a co-located robot, especially a non-anthropomorphic robot, over presence of another human or alone for introvert or female participants during hard tasks. We observed an increase in number of drags, an improvement in emotional state, such as lower arousal and higher valence, and higher desirability ratings. These findings can serve as guidelines for future HRI researchers when designing robots around people.

II. Related Work

A. Motivation

Motivation is the driving force behind human actions. Motivation can be assessed by cognitive measures, e.g., the user's goal-related associations and experiences, as well as by behavioral measures, e.g., the time the user spent in the task and their performance [12]. Motivation can be intrinsic, which originates from within when working on a joyful, interesting, or challenging task; and extrinsic, which originates from outside in the form of persuasion, praise, rewards, etc [12], [13].

The presence of others can cause as motivational losses via social loafing [14], as well as gains through social compensation and the Köhler effect [15]. This dual effect is also manifested in social facilitation with task performance. Social facilitation suggests that the presence of others, as a source of arousal, can influence an individual's performance in a task in which the individual is competent, and as a result increase their motivation [16]. In the existing literature, the influence of mere presence is typically projected to the intrinsic motivation [17], [18]. In [17], authors report that if the surveillance - either in person or via a camera - manifests controlling intentions, participants demonstrate lower intrinsic motivation compared to the non-controlling intention and no-surveillance conditions. In [18], authors demonstrated that the mere presence of an anthropomorphic robot in a digital task increased participants' intrinsic motivation.

B. Motivational robots

Researchers have begun to investigate the use of anthropomorphic robots to facilitate motivation. Baylor argued that an anthropomorphic appearance is a key factor in promoting motivation [3]. Song et al. [19] found that human motivation can be influenced by how evaluative the co-presented robot is. Different robot behaviors were also explored as persuasion means for increasing users' extrinsic motivation such as vocal cues [20], bodily gesture [6], and touch [21]. Winkle et al. [4] have shown that robots that display goodwill and similarity to the participant are more persuasive. However, all the mentioned studies rely on anthropomorphic features of the robots, which many of the currently commercial robots do not possess and can set false expectations about their social skills. In this paper, we seek to understand what role the anthropomorphism of a co-located robot plays in affecting humans' motivation and emotion by comparing a non-anthropomorphic robot with an anthropomorphic robot.

C. Personality in HRI

Existing research in HRI demonstrates that the personalities of humans and robots influence human-robot interaction. Out of the different personality traits, extroversion is the most commonly studied trait in HRI [9].

Robots' personalities are derived based on their appearance and behavior [10]. HRI researchers convey robots' personalities through appearance, vocal features, body movements, facial expression, and haptics/proxemics [11]. Compared to introverted robots, extroverted robots were designed to speak more with varied pitch and with higher volume, move faster with larger and more frequent motion, and have faces that radiate with smile along with big eyes making frequent eye contact with the users [11], [9]. In general, humanoid robots are perceived as more extroverted compared to non-humanoid robots [22].

With respect to the influence of the human personality on human-robot interaction, existing research suggests that introverts are more reserved when interacting with robots, whereas extroverts generally express more open and positive attitude towards robots [9] and are also more likely to attribute human-like qualities to robots [23]. The literature suggests that in collaborative scenarios people prefer interacting with robots of similar personalities [24], however, there is evidence that opposite personalities may also lead to productive collaboration [25].

D. Gender in HRI

Prior studies suggest that people of different genders perceive and react to robots differently. In particular, various studies, summarized in a review by Nomura, have found that women generally had more negative attitudes about the interaction with robots and about the social impact and usefulness of the robot than men [26]. However, these studies either involve human-like robots or do not specify the type of robots to participants. Thus, the interplay between robot's anthropomorphism and human gender is not understood. In this work, we investigate how those two factors affect one another in the context of motivation and emotion.

III. Method

To explore the effects of a co-located robot and its anthropomorphism on people's motivation and emotion, we designed an experiment where participants performed a repetitive task within a virtual environment under four presence conditions: an anthropomorphic and a non-anthropomorphic robots, a human, and alone.This study was approved by the University's Institutional Review Board with participants providing informed consent.

A. Hypotheses

HRI literature [9], [10], [11] suggests a variety of factors that can determine how a co-located robot affects human's motivation and emotion: the appearance and behavior of the robots, the personality and gender of the human. The context, such as task or the difficulty of the task, can also determine how the presence of others impact the user's task performance [16].

While researchers have studied various non-human agents to increase the motivation level of users, none have studied the effects of the mere presence of a co-located robot, especially that of a non-anthropomorphic robot, and compared it with a human presence and being alone. Given prior evidence on robotic presence facilitating or inhibiting user task performance based on the task difficulty and anthropomorphism [27], [28], we hypothesize that robotic presence will also facilitate or inhibit the user's motivation and emotion to a different extent relative to human presence or alone depending on the task difficulty and the anthropomorphism. Specifically, prior work showed that surveillance with controlling intentions lowers intrinsic motivation [17] and a person who elicits evaluation apprehension leads to worse performance for hard tasks [29]. We conjecture that the anthropomorphism of the robot will contribute to how people perceive the robot in terms of its intention and evaluation capability. Thus, we hypothesize that:

H1. An anthropomorphic robot and human presence will lead to worse motivational level (i.e., fewer repetitions and lower working time) and emotional state (i.e., higher arousal but lower valence, dominance, and desirability) than a non-anthropomorphic robot and alone, especially for hard tasks.

Personality and gender of the human will also mediate how a co-located robot affects human's motivation and emotion. In particular, prior work shows that extroverts prefer interaction with robots [9] and respond more effectively to the presence of motivators compared to introverts [30] while men report more positive emotion toward robots than women [26]. Thus, we hypothesize that:

H2. Extroverted people will be more motivated (i.e., more repetitions, higher working time) and comfortable (i.e., lower arousal but higher valence, dominance, and desirability) with the robotic presences than introverted people.

H3. Male participants will be more motivated (i.e., more repetitions, higher working time) and comfortable (i.e., lower arousal but higher valence, dominance, and desirability) with the robotic presences than female participants.

B. Independent Variables

We had two variables: presence and task difficulty.

1) Presence: We had four presences: non-anthropomorphic robot, anthropomorphic robot, human, and alone. For the robot presences, we used mobile robots of binary levels of anthropomorphism as shown in Figure 2: a non-anthropomorphic robot and an anthropomorphic robot. We grounded the robot design on simple table-top robots like the Zooids [31]. For the non-anthropomorphic version of the robot, we took their original design, a simple cylindrical shape. For the anthropomorphic robot, we enhanced the non-anthropomorphic robot design with animated eyes blinking at a rate similar to the human's [32]. We decided to add only the eyes because the presence of eyes is the most significant facial feature on robot heads for perception of humanness [33]. In support of this observation, robot head designs with only eyes are widely applied in many of existing commercial robots, such as Amazon Astro, Jibo, and Nio Nomi.

For the human presence, a pre-recorded video of a human observer was displayed as shown in Figure 2. The facial expression of the human observer was kept neutral to prevent eliciting any extreme emotion from the study participants. For the alone presence, only the task and task-related information were shown to the participant in the scene shown in Figure 2, the video frame and robots were hidden.

2) Task Difficulty: Social facilitation demonstrates the importance of task difficulty on how presence of others either facilitates or inhibits performance. Similarly, we believe task difficulty may have an impact on how a co-located robot affects humans' motivation and emotion. To study this, we created a hard and easy versions of the task. While the task difficulty is usually a within-subjects variable, our pilot study with 20 participants and a setup identical to the main study revealed that there was a large discrepancy in participant's effort levels between the first and second trials. Thus, we decided to make task difficulty a between-subjects variable, where each participant only experiences either the hard or easy version of the task.

C. Measurements

1) Behavioral Data for Motivation: As a behavioral proxy for participants' level of motivation, we measured their task performance under different presences and task difficulties. For each participant, we recorded the total time spent in the task, the number of drags completed, and the average drag duration using the former two measures.

2) Self-Reported Perception: In addition to the performance-related measures, we gathered participants' quantitative and qualitative feedback on their experience. Specifically, we asked participants to self-report their emotion through SAM (Self-Assessment Manikin) [34] and sense of being evaluated on a 7-point Likert scale. We also got ratings on their perception of the robot in terms of anthropomorphism and animacy using the Godspeed questionnaire [35], and their desirability for the robot using the Adoption Likelihood Factors Questionnaire [36]. Qualitatively, we asked participants about a) the noticeability of the robots (i.e., whether the user noticed the robots and how they perceived them), b) the affective influence of the robots (i.e., how they perceived the presence of the robots and robot's affect on their emotion) and c) the desirability of the robots (i.e., whether the user could imagine using such robots on a daily basis).

3) Personality: To measure the extroversion-introversion dimension of the Big-Five personality, we asked the participants to rate the following statements, "I see myself as extroverted/enthusiastic or reserved/quiet", on a 7-point Likert scale and used the average of the two ratings; this approach is in line with the instrument from Gosling et al. [37]. As done by Andrist et al. [5], we looked at the distribution of the extroversion ratings to determine the threshold between extroverts and introverts. Given that the mean was 2.98 and the median was 3, 75 participants with ratings higher than 3 were labelled as an "extrovert" and 87 participants with ratings lower than 3 as an "introvert".

D. Study Setup

The study was conducted in a virtual 3D environment running in a browser. The software, developed in Unity 3D, comprises 3D scenes of the experiment, functionality for generating the repetitive task of easy/hard complexity and rendering the presence conditions, and functionality for logging the user's performance in the task. The software was made accessible as a web page. Participants navigated to the web page using a personal link with a unique participant id and the condition type as parameters (generated by Qualtrics). Performance of each participant was saved to a separate file.

The main 3D scene of the experiment, shown in Figure 2, resembles a typical context for office work: a desk with a A4-sized paper on it. The paper includes the study task elements: the draggable circle and the target square. For the robot

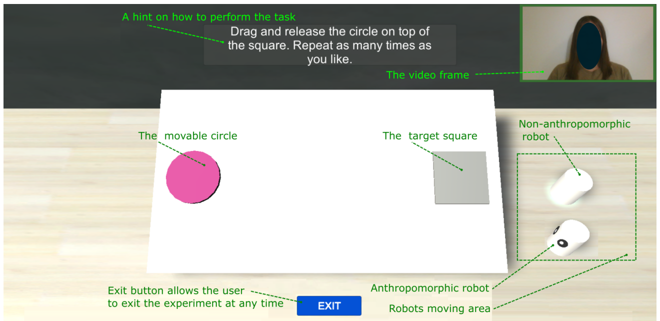

Fig. 2. The main scene of the experiment includes the task elements (i.e., a circle and a square on a white paper in the center), instruction text on the top, and the different presence conditions (i.e., a video of a human, non-anthropomorphic, and anthropomorphic robot), which are shown all at once for demonstration purposes in this image but during the experiment, at most one of the presences is visible.

presence conditions, we had the robots move randomly at a speed between the fast and slow reported in [38] (12 cm/s) within a designated moving area on the right side of the paper because motion has been heavily linked with the perceived animacy of an object and most commercially available robots are mobile. How the robot moves also impacts human perception and thus we chose a random movement to elicit more neutral emotion [38]. For the non-anthropomorphic robot, increasing the perceived animacy via motion was especially important because otherwise participants would not have perceived the robot as an animate agent [39], [40]. For the human presence condition, a video frame looping a pre-recorded video of a human observer appears in the right upper corner of the screen. To make the human presence more realistic, we designed the video frame similar to a typical minimized online conference call window like Zoom.

E. Task

Participants were asked to complete a repetitive dragging task used in prior work [41]. In this task, the users should use their mouse pointer to drag and drop a circle on top of a designated square as shown in Figure 2. When the circle is dragged to the square so that the center of the circle lies within the square, the color of the circle changes to green to indicate a successful drag; when the mouse is then released, the circle reappears on the left side of the paper for the next trial. The participant is instructed to complete as many drags as possible but can exit at anytime by clicking the exit button at the bottom of the scene.

To implement the easy and hard difficulties of the task, we used the Fitts's law to decide the task parameters [42]:

$$ID = log_2(\frac{2D}{W}) \quad (1)$$

where, in the context of our study, ID is the index of difficulty, D is the distance between the center of the circle and the center of the square, and W is the width of the square. For the study, we made the ID of the easy task to be half of that of the hard task (i.e., $ID_{easy} = \frac{1}{2} * ID_{hard}$). To have the same starting points, we kept the same distance between the objects ($D = 1$), but we varied the sizes of the circle and square for each difficulty ($W_{easy} = 0.2$ and $W_{hard} = 0.02$).

F. Procedure

The study was conducted using Prolific and Qualtrics. Prolific served as the entry point to the study from where the participants proceeded to Qualtrics. Once in Qualtrics, the participant got the link to the study with their unique participant id and the condition type generated for each participant; the conditions were distributed as equally between the participants as possible using Qualtrics.

On accessing the study link, the users saw a welcoming screen with a brief introduction. In particular, the participants were encouraged to enter the full screen mode and wear headphones to listen to the white noise during the experiment. Participants were notified about the possible presence of an observer in the experiment, but no particular details were revealed. Next, the participants received a description and instruction of the dragging task and were asked to complete as many drags in the task as they could. The task started with a practice session where the participants could experience the dragging and receive feedback from the system. Once the participants were familiar enough with the task, they proceeded to the main session where they were presented with the task of either easy or hard difficulty. Right after completing the main session, the participants completed a short questionnaire to measure emotion (arousal, valence, and dominance) and their sense of being evaluated on a 7-point Likert scale. After the study, the participants were redirected back to Qualtrics for the post-study questionnaire.

G. Participants

We recruited 242 participants through Prolific for a between-subjects study. Approximately 25 participants were assigned per presence condition and per task difficulty. For quality control, only participants that satisfy the following requirements were included in the analysis: 1) located in the US, 2) their approval rate is greater than 90, 3) the number of HITs approved was greater than 50, and 4) he/she has completed both the task and the post-study questionnaire.

Requirements 1-3 were enforced through Prolific. For requirement 4, we removed 32 participants who did not complete either the task or the post-study questionnaire. We removed 28 outliers based on their completion time and number of drags completed (i.e., $< Q3 + 1.5(Q3 - Q1)$ and $> Q1 - 1.5(Q3 - Q1)$). The computed thresholds for completion time and number of drags were $t < 72.4s$ and $n_{drag} < 26$ respectively.

For the analysis, 182 participants (83 male, 92 female, 7 non-binary) with a mean age of 33.1 years (SD = 10.3) were included. 24.2%, 65.4% and 10.4% of participants reported education levels of middle/high school, college, and advanced degrees, respectively. Participants were compensated at the rate of $15 per hour for the time spent on the study. On average, participants spent a total of 6 minutes (SD = 3.3 min). None of the participants had neurological disorders, impaired vision, headache, fatigue, or any other conditions that may have affected their performance in this experiment.

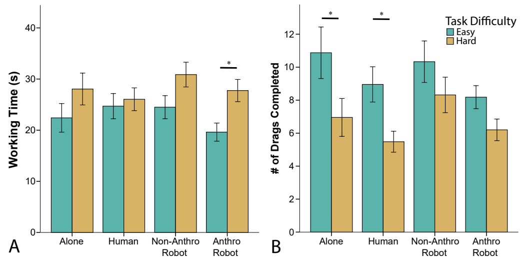

Fig. 3. Working time and number of drags completed are shown for each presence at two difficulty levels.

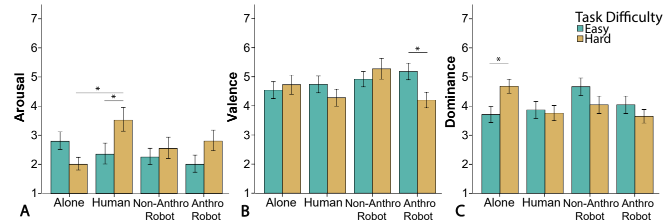

Fig. 4. (A) Arousal, (B) valence, and (C) dominance ratings for each presence condition under both task difficulties.

H. Data Analysis

To examine the effects of the presence and task difficulty including interaction, a Levene's Test of Equality of Error Variances and an ANOVA were performed for each behavioral data and self-reported perception ratings. To compare across different presences and task difficulties, we used a 4 x 2 ANOVA with two between-subject factors. If any independent variable or combinations had statistically significant ($p < .05$) or were close ($p < 0.1$), Bonferroni-corrected post-hoc tests were used to determine if and which pairs were significantly different.

To study interaction effects with personality and gender, we ran two 3-way ANOVAs for personality and gender separately as there were different data filtering processes necessary for each. For instance, only participants with ratings higher or lower than the median were included so that they could be labelled as extrovert and introverts. In contrast, for gender, only female or male participants were included for the analysis with gender as there were only 7 non-binary participants. For both personality and gender, we conducted a 2 x 4 x 2 (personality/gender x presence x task difficulty) ANOVA with three between-subject factors. If any independent variable or combinations had statistically significant ($p < .05$) or were close ($p < 0.1$), Bonferroni-corrected post-hoc tests were used to determine if and which pairs were significantly different.

IV. Results

We summarize our study findings in terms of behavioral data and user perception (e.g., emotion, perceived anthropomorphism, perceived animacy, and desirability) from the self-reported questionnaire. We first report the overall results followed by results across personality and gender. Figures 3-9 plot the means and standard errors of the results.

A. *H1:* Overall Effects of Robotic Presence

1) Behavioral Data: Figure 3 shows the working time and number of drags completed for easy and hard task difficulties. As expected, the task difficulty had statistically significant effects on both the working time ($F(1,174) = 9.63, p = .002, \eta^2 = .052$) and number of drags completed ($F(1,174) = 14.0, p < .001, \eta^2 = .074$). The participants who completed the hard difficulty performed fewer drags (hard: M = 6.74, SE = 0.55, easy: M = 9.59, SE = 0.53) and worked for a longer time (hard: M = 28.2 s, SE = 1.2 s, easy: M = 22.8 s, SE = 1.2 s) than those who completed easy difficulty. The average times to complete a drag for each of the difficulties were 0.24 seconds and 0.42 seconds, which matches the 1:2 difficulty ratio we designed using the Fitts' law.

The presence variable had a close to statistically significant effect on the number of drags completed ($F(3,174) = 2.16, p = .095, \eta^2 = .036$). As shown in Figure 3, the non-anthropomorphic robot presence led to the highest number of drags completed (M = 9.33, SE = 0.76) while the human presence (M = 7.22, SE = 0.74) and anthropomorphic robot presence (M = 7.20, SE = 0.79) led to the fewest number. Non-anthropomorphic robot also led to the longest working time, especially for the hard task (M = 30.9 s, SE = 2.5 s).

As shown in Figure 3, there are statistically significant interaction effects between the task difficulty and presence in number of drags completed between the two task difficulties for the alone ($p = 0.01$) and human ($p = 0.02$) presences, but not for the non-anthropomorphic or anthropomorphic robot presences. In terms of working time, only the anthropomorphic robot presence led to statistically significant difference between the two difficulty levels ($p = .025$).

2) Self-Reported Perception: Neither the task difficulty nor the presence variables alone had a statistically significant main effect on any of the emotion variables or the sense of being evaluated. Instead, there were interaction effects between the task difficulty and presence on arousal ($F(3,174) = 3.43, p = .018, \eta^2 = .056$), valence ($F(3,174) = 2.06, p = .10, \eta^2 = .034$), and dominance ($F(3,174) = 3.27, p = .023, \eta^2 = .053$).

As shown in Figure 4, human presence led to a higher level of arousal than alone for hard tasks, while with human presence, hard tasks yielded a higher level of arousal than easy tasks. For valence, with anthropomorphic robots, hard tasks were less pleasant than easy tasks. For dominance, participants felt more dominant with hard tasks than for easy tasks when alone.

For both the perceived anthropomorphism and animacy of the robots, there were no statistically significant differences. In terms of desirability, the presence had a statistically significant main effect ($F(2,136) = 9.64, p < .001, \eta^2 = .129$). Both non-anthropomorphic and anthropomorphic robots were rated more desirable than the human as shown in Figure 5A.

3) Qualitative Response on Noticeability and Perceived Influence of the Robot: 88 participants were assigned to robotic presence conditions - either non-anthropomorphic or anthropomorphic. 36 out of the 88 participants perceived the robot as a distraction. For example, when asked what they

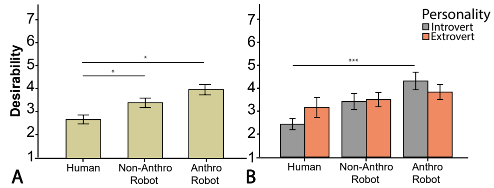

Fig. 5. Desirability ratings across (A) all participants and (B) personality

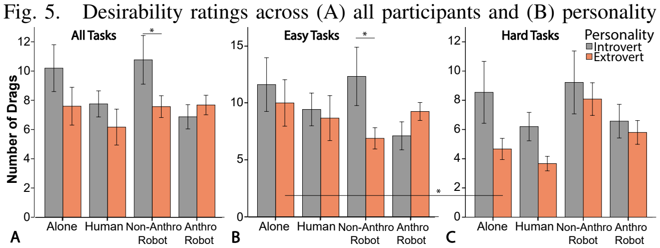

Fig. 6. Number of drags completed across presence and personality in (A) all tasks, (B) easy tasks, and (C) hard tasks

thought about the robot, P25 wrote: "Nothing much, other than that it was there to distract me. So I avoided looking at it." 24 out of the 88 participants perceived the robot as an observer, as P54 stated "It felt like it was watching my movements and studying my ability to complete the task. Its movements and blinking made it feel lifelike, and as if there was an AI behind it evaluating me." Eight out of 42 people in the anthropomorphic robot condition thought the robot was cute and enjoyed its presence, for instance, P27 mentioned that "I just thought he was cute, felt like I wasn't alone." Two out of 46 people who were in the non-anthropomorphic robot condition expressed positive feelings about the robot, as P39 wrote: "I liked it. It was moving around but never in an annoying way and it felt soothing in a weird way."

B. *H2: Effects of Robotic Presence across Personality*

1) Behavioral Data: Personality had a statistically significant main effect on number of drags completed ($F(1,146) = 4.33, p = .039, \eta^2 = .029$). Introverts ($m = 8.88, SE = .6$) completed more drags than extroverts ($m = 7.13, SE = .6$).

As shown in Figure 6, personality also had interaction effects with presence and task difficulty. In the presence of non-anthropomorphic robot, introverts completed more drags ($p = .05$) as shown in Figure 6A. In particular, this was observed for easy tasks ($p = .027$) and not for hard tasks as shown in Figures 6 B and C. Extroverts also completed more drags for easy tasks than hard tasks when alone ($p = .023$).

2) Self-Reported Perception: Personality had statistically significant effects with presence and task difficulty on arousal, valence, and desirability. As shown in Figure 7, for easy tasks, introverts found the anthropomorphic robot less arousing than when alone ($p = .014$) or compared to extroverts ($p = .041$). Introverts also found the anthropomorphic robot less arousing for easy tasks than hard tasks ($p = .024$).

In terms of valence, introverts rated the anthropomorphic robot higher than alone ($p = .038$) for easy tasks and rated it higher for easy tasks compared to hard tasks ($p = .014$) as shown in Figure 7. On the other hand, extroverts rated the non-anthropomorphic robot higher than human ($p = .027$).

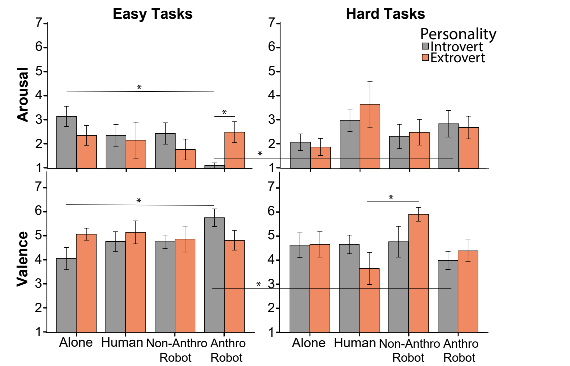

Fig. 7. Ratings for arousal and valence across presence, personality, and task difficulty

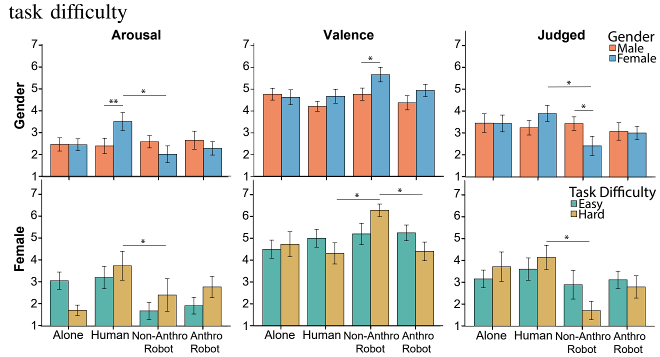

Fig. 8. Ratings for feeling judged, arousal, and valence across presence, gender, and task difficulty

As shown in Figure 5B, introverts found the anthropomorphic robot more desirable than the human ($p < .001$).

C. *H3: Effects of Robotic Presence across Gender*

1) Behavioral Data: Gender had a statistically significant effect on the drag duration ($F(1,159) = 6.67, p = .011, \eta^2 = .04$). Male participants ($m = 3.4s, SE = .4s$) completed each drag more quickly than their female counterparts ($m = 4.9s, SE = .4s$).

2) Self-Reported Perception: As shown in Figures 8, gender had statistically significant interaction effects with presence and task difficulty on arousal, valence, and the sense of being judged. As shown in Figure 8, female participants rated the human presence higher in arousal ($p = .023$) and sense of being judged ($p = .027$) than the non-anthropomorphic robot. The average judged rating was also significantly lower for female compared to male participants ($p = .039$), while the ratings for the arousal of human presence ($p = .006$) and valence of non-anthropomorphic robot ($p = .025$) were higher for female participants than male participants.

In particular, as shown in Figure 8, female participants rated the non-anthropomorphic robot significantly lower in the sense of being judged ($p = .019$) than human presence and higher in valence than human ($p = .019$) and anthropomorphic robot ($p = .045$) for hard tasks only. Human presence also led to significantly higher arousal rating from female participants for hard tasks ($p = .009$).

Gender also had a statistically significant interaction effect with presence on perceived anthropomorphism and animacy, as well as desirability. In particular, as shown in Figure 9,

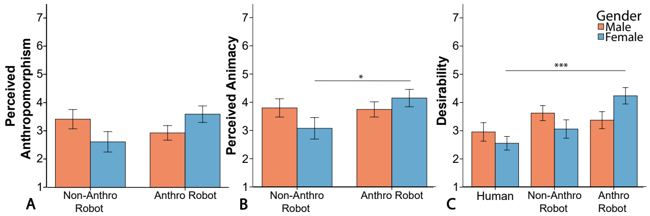

Fig. 9. Ratings for (A) perceived anthropomorphism, (B) animacy, and (C) desirability across gender and presence

female participants found the anthropomorphic robot higher in perceived anthropomorphism ($p = .056$) and animacy ($p = .04$) whereas male participants did not. Female participants also rated the desirability of the anthropomorphic robot higher than that of the non-anthropomorphic robot ($p = .051$) and human presence ($p < .001$).

V. Discussion

While participants preferred the robotic presences over the human presence in terms of desirability, there were only subtle behavioral evidence in support of H1. In particular, across both easy and hard tasks, the non-anthropomorphic robot presence led to the highest number of completed drags and longest working time, while the anthropomorphic robot and human presence resulted in the fewest number of drags. Albeit statistically non-significant, this trend agrees with results from existing literature that suggest the presence of eyes makes people feel watched [43] and presence of others without surveillance intent facilitates motivation [17]. This effect size may be further strengthened with physically present robots instead of virtual robots [44] and thus should be investigated in the future.

Both the personality and gender of the participants mediated the effects of the co-located robot on their motivation and emotion. In terms of motivation, introverts completed more drags than extroverts for easy tasks in the presence of a non-anthropomorphic robot. Emotionally, introverts felt less aroused and more pleasant with an anthropomorphic robot than alone under easy tasks, while extroverts found the non-anthropomorphic robot more pleasant than the human under hard tasks. Introverts also rated the anthropomorphic robot higher than human in terms of desirability while extroverts did not rate the presences differently. While prior literature found that extroverts were more comfortable with robots than introverts [45], our study results suggest that the user's preferences depend on not only their personality but also the task difficulty and the anthropomorphism of the robot, a result different from H2.

The gender of the participants influenced how they perceived the robots in terms of emotion, desirability, and perceived anthropomorphism and animacy. Overall, we observed that the female participants perceived the robotic presences more positively than the male participants, rejecting H3 and in contrast to prior literature [26]. In particular, female participants felt more judged, aroused, and unpleasant with the human presence than with the non-anthropomorphic robot, especially during hard tasks. On the other hand, male participants did not perceive any of the presences differently. Similarly, while female participants rated the robot presences more desirable than the human, male participants did not rate any higher than the other. In terms of perceived anthropomorphism and animacy, female participants rated the anthropomorphic robot higher than the non-anthropomorphic robot, while the male participants did not. These results indicate the anthropomorphism of the robot should be carefully designed especially for female users to elicit a desired affective state. In addition, since we only used a female human presence, further investigation should be conducted with both male and female human presences.

One limitation of our study is that we did not measure the user's perception of the robots' introversion/extroversion. While we did not deliberately design the personality of the robots, we treated the non-anthropomorphic robot's design as introverted: the robot's appearance is mechanic, the robot is not interactive, and is rather reserved and monotonous in its movement. We expected that adding eyes to the robot would insignificantly increase its perceived extroversion: even though big eyes are a trait of extroversion in HRI, absence of eye contact is a sign of introversion [11], [9]. Following this logic, as well as the evidence from HRI literature that people prefer collaborating with robots of similar personality [24], we expected to see that introverts would prefer the non-anthropomorphic robot over the anthropomorphic, and the opposite in the case of extroverts. In practice, both extroverts and introverts found anthropomorphic robot more desirable. Further investigation into this issue may explain this observation.

VI. Conclusion

This paper seeks to understand how a co-located robot affects people's motivation and emotion. We also explore how the role of anthropomorphism of the robot and the personality and gender of the users mediate the effect. Our virtual study provides some support, both performance-related and perceptual, to the use of the non-anthropomorphic robot presence over the presence of a human or an anthropomorphic robot, especially for introverts and female users during hard tasks. These findings can serve as guidelines for future robot developers as they apply not only to social robots with direct interaction with users but any mobile robot that co-exists in the same space with people.

References

[1] A. Baylor, "Beyond butlers: Intelligent agents as mentors," *Journal of educational computing research*, vol. 22, no. 4, pp. 373–382, 2000.

[2] T. Breuer, G. R. G. Macedo, R. Hartanto, N. Hochgeschwender, D. Holz, F. Hegger, Z. Jin, C. Müller, J. Paulus, M. Reckhaus, *et al.*, "Johnny: An autonomous service robot for domestic environments," *Journal of intelligent & robotic systems*, vol. 66, no. 1, pp. 245–272, 2012.

[3] A. L. Baylor, "Promoting motivation with virtual agents and avatars: role of visual presence and appearance," *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 364, no. 1535, pp. 3559–3565, 2009.

[4] K. Winkle, S. Lemaignan, P. Caleb-Solly, U. Leonards, A. Turton, and P. Bremner, "Effective persuasion strategies for socially assistive robots," in *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 2019, pp. 277–285.

[5] S. Andrist, B. Mutlu, and A. Tapus, "Look like me: matching robot personality via gaze to increase motivation," in *Proceedings of the 33rd annual ACM conference on human factors in computing systems*, 2015, pp. 3603–3612.

[6] I. Baroni, M. Nalin, M. C. Zelati, E. Oleari, and A. Sanna, "Designing motivational robot: how robots might motivate children to eat fruits and vegetables," in *The 23rd IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 2014, pp. 796–801.

[7] F. Levillain and E. Zibetti, "Behavioral objects: The rise of the evocative machines," *Journal of Human-Robot Interaction*, vol. 6, no. 1, pp. 4–24, 2017.

[8] J. Złotowski, D. Proudfoot, K. Yogeeswaran, and C. Bartneck, "Anthropomorphism: opportunities and challenges in human–robot interaction," *International journal of social robotics*, vol. 7, no. 3, pp. 347–360, 2015.

[9] L. Robert, R. Alahmad, C. Esterwood, S. Kim, S. You, and Q. Zhang, "A review of personality in human–robot interactions," *Available at SSRN 3528496*, 2020.

[10] S. You and L. Robert, "Emotional attachment, performance, and viability in teams collaborating with embodied physical action (epa) robots," *You, S. and Robert, LP (2018). Emotional Attachment, Performance, and Viability in Teams Collaborating with Embodied Physical Action (EPA) Robots, Journal of the Association for Information Systems*, vol. 19, no. 5, pp. 377–407, 2017.

[11] Y. Mou, C. Shi, T. Shen, and K. Xu, "A systematic review of the personality of robot: mapping its conceptualization, operationalization, contextualization and effects," *International Journal of Human–Computer Interaction*, vol. 36, no. 6, pp. 591–605, 2020.

[12] M. Touré-Tillery and A. Fishbach, "How to measure motivation: A guide for the experimental social psychologist," *Social and Personality Psychology Compass*, vol. 8, no. 7, pp. 328–341, 2014.

[13] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary educational psychology*, vol. 25, no. 1, pp. 54–67, 2000.

[14] B. Latané, K. Williams, and S. Harkins, "Many hands make light the work: The causes and consequences of social loafing." *Journal of personality and social psychology*, vol. 37, no. 6, p. 822, 1979.

[15] W. Stroebe, M. Diehl, and G. Abakoumkin, "Social compensation and the köhler effect: Toward a theoretical explanation of motivation gains in group productivity," *Understanding group behavior*, vol. 2, pp. 37–65, 1996.

[16] R. B. Zajonc, "Social facilitation," *Science*, vol. 149, no. 3681, pp. 269–274, 1965.

[17] M. E. Enzle and S. C. Anderson, "Surveillant intentions and intrinsic motivation." *Journal of personality and social psychology*, vol. 64, no. 2, p. 257, 1993.

[18] J. Mumm and B. Mutlu, "Designing motivational agents: The role of praise, social comparison, and embodiment in computer feedback," *Computers in Human Behavior*, vol. 27, no. 5, pp. 1643–1650, 2011.

[19] H. Song, Z. Zhang, E. I. Barakova, J. Ham, and P. Markopoulos, "Robot role design for implementing social facilitation theory in musical instruments practicing," in *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 2020, pp. 253–260.

[20] K. Nakagawa, M. Shiomi, K. Shinozawa, R. Matsumura, H. Ishiguro, and N. Hagita, "Effect of robot's whispering behavior on people's motivation," *International Journal of Social Robotics*, vol. 5, no. 1, pp. 5–16, 2013.

[21] ——, "Effect of robot's active touch on people's motivation," in *Proceedings of the 6th international conference on Human-robot interaction*, 2011, pp. 465–472.

[22] M. L. Walters, D. S. Syrdal, K. Dautenhahn, R. Te Boekhorst, and K. L. Koay, "Avoiding the uncanny valley: robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion," *Autonomous Robots*, vol. 24, no. 2, pp. 159–178, 2008.

[23] A. D. Kaplan, T. Sanders, and P. A. Hancock, "The relationship between extroversion and the tendency to anthropomorphize robots: A bayesian analysis," *Frontiers in Robotics and AI*, p. 135, 2019.

[24] E. Park, D. Jin, and A. P. del Pobil, "The law of attraction in human-robot interaction," *International Journal of Advanced Robotic Systems*, vol. 9, no. 2, p. 35, 2012.

[25] K. M. Lee, W. Peng, S.-A. Jin, and C. Yan, "Can robots manifest personality?: An empirical test of personality recognition, social responses, and social presence in human–robot interaction," *Journal of communication*, vol. 56, no. 4, pp. 754–772, 2006.

[26] T. Nomura, "Robots and gender," *Gender and the Genome*, vol. 1, no. 1, pp. 18–25, 2017.

[27] N. Riether, F. Hegel, B. Wrede, and G. Horstmann, "Social facilitation with social robots?" in *2012 7th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 2012, pp. 41–47.

[28] L. H. Kim, V. Domova, Y. Yao, C.-M. Huang, S. Follmer, and P. E. Paredes, "Robotic presence: The effects of anthropomorphism and robot state on task performance and emotion," *IEEE Robotics and Automation Letters*, pp. 1–8, 2022.

[29] N. B. Cottrell, "Social facilitation," *Experimental social psychology*, vol. 185, p. 236, 1972.

[30] A. Nuckcheddy, "The effect of personality on motivation and organisational behaviour," *Psychology and Behavioral Science International Journal*, vol. 9, no. 2, pp. 1–5, 2018.

[31] M. Le Goc, L. H. Kim, A. Parsaei, J.-D. Fekete, P. Dragicevic, and S. Follmer, "Zooids: Building blocks for swarm user interfaces," in *Proceedings of the 29th Annual Symposium on User Interface Software and Technology*, 2016, pp. 97–109.

[32] K.-A. Kwon, R. J. Shipley, M. Edirisinghe, D. G. Ezra, G. Rose, S. M. Best, and R. E. Cameron, "High-speed camera characterization of voluntary eye blinking kinematics," *Journal of the Royal Society Interface*, vol. 10, no. 85, p. 20130227, 2013.

[33] C. F. DiSalvo, F. Gemperle, J. Forlizzi, and S. Kiesler, "All robots are not created equal: the design and perception of humanoid robot heads," in *Proceedings of the 4th conference on Designing interactive systems: processes, practices, methods, and techniques*, 2002, pp. 321–326.

[34] M. M. Bradley and P. J. Lang, "Measuring emotion: the self-assessment manikin and the semantic differential," *Journal of behavior therapy and experimental psychiatry*, vol. 25, no. 1, pp. 49–59, 1994.

[35] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *International journal of social robotics*, vol. 1, no. 1, pp. 71–81, 2009.

[36] TryMyUI, "The alfq and usability testing," 2021. [Online]. Available: https://trymyui.com/alfq

[37] S. D. Gosling, P. J. Rentfrow, and W. B. Swann Jr, "A very brief measure of the big-five personality domains," *Journal of Research in personality*, vol. 37, no. 6, pp. 504–528, 2003.

[38] L. H. Kim and S. Follmer, "Ubiswarm: Ubiquitous robotic interfaces and investigation of abstract motion as a display," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 1, no. 3, pp. 1–20, 2017.

[39] F. Heider and M. Simmel, "An experimental study of apparent behavior," *The American journal of psychology*, vol. 57, no. 2, pp. 243–259, 1944.

[40] J.-H. Lee, J.-Y. Park, and T.-J. Nam, "Emotional interaction through physical movement," in *International Conference on Human-Computer Interaction*. Springer, 2007, pp. 401–410.

[41] M. Shiomi, K. Nakagawa, K. Shinozawa, R. Matsumura, H. Ishiguro, and N. Hagita, "Does a robot's touch encourage human effort?" *International Journal of Social Robotics*, vol. 9, no. 1, pp. 5–15, 2017.

[42] P. M. Fitts, "The information capacity of the human motor system in controlling the amplitude of movement." *Journal of experimental psychology*, vol. 47, no. 6, p. 381, 1954.

[43] K. Dear, K. Dutton, and E. Fox, "Do 'watching eyes' influence antisocial behavior? a systematic review & meta-analysis," *Evolution and Human Behavior*, vol. 40, no. 3, pp. 269–280, 2019.

[44] J. Li, "The benefit of being physically present: A survey of experimental works comparing copresent robots, telepresent robots and virtual agents," *International Journal of Human-Computer Studies*, vol. 77, pp. 23–37, 2015.

[45] L. Robert, "Personality in the human robot interaction literature: A review and brief critique," in *Robert, LP (2018). Personality in the Human Robot Interaction Literature: A Review and Brief Critique, Proceedings of the 24th Americas Conference on Information Systems, Aug*, 2018, pp. 16–18.