Team Robot Identification Theory (TRIT): Robot Attractiveness and Team Identification on Performance and Viability in Human–Robot Teams

Sangseok You*
Sungkyunkwan University (SKKU)
25-2 Sungkyunkwan-ro, Jongno-gu
Seoul, Republic of Korea
sangyou@skku.edu

Lionel P. Robert Jr.
University of Michigan
105 S. State St.
Ann Arbor, MI, USA
lprobert@umich.edu

* Corresponding author

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ABSTRACT

Prior literature suggests that shared identity and social attraction between team members and their robots can be vital for the human–robot interaction. However, more attention is needed to understand the potential performance benefits associated with team identification (TI) and robot attractiveness in human–robot teams. We proposed a theoretical framework of team robot identification theory. We conducted a laboratory experiment to examine the impacts of TI and social attraction toward robots on team performance and viability in 30 human–robot teams comprising two humans and two physical robots. Results showed that TI in human–robot teams led to better performance and team viability. Both effects were mediated by the social attraction between team members and their robots. These results evidenced the direct links between TI and objective and subjective team outcomes, explained through social attraction toward robots. We discuss the results and their theoretical and practical implications.

Keywords: robot attractiveness, identification, social attraction, performance, team viability, human–robot teams

1. Introduction

In recent decades, robots have become an emerging collaborative technology in teams. Teams are beginning to rely on robots to accomplish their work in several settings [1, 2]. For example, remote-controlled robots are often paired with humans and deployed in urban search and rescue teams [3–5]. Moreover, robots are paired with medical teams to perform advanced surgery [6]. They are also used in traditional work settings [7]. However, despite the growing incorporation of robots in teams, we are just beginning to understand what factors are essential to promoting better performance in such teams [1, 4]. Teamwork with robots represents an opportunity to extend the long tradition of studying how interactions between teams and their information technology can improve team performance.

Research on teamwork with robots requires an understanding of what leads to better teamwork and better interaction with robots [1, 4]. On the one hand, robots are technology artifacts that teams employ to accomplish their work [4]. Previous research has shown that attitudes and feelings toward technology can have important implications for the job performance associated with the technology [8]. This is particularly true for teamwork with technology [9]. On the other hand, robots are a type of embodied technology that individuals often prescribe human attributes, intentions, and actions [10–12]. Taken together, individuals often form relationships with robots in much the same way they do with humans [13]. To better understand teamwork with robots, we have to draw from the literature on teamwork and human–robot interaction (HRI).

Social attraction (i.e., robot attractiveness), defined as the degree to which an entity elicits positive perceptions from other entities and individuals, has been significant across the literature on both teamwork and HRI [11, 14, 15]. However, the literature on social attraction and robots has several shortcomings. First, although the social attraction has been shown to promote better interactions between humans and robots, much less attention has been paid to whether social attraction can lead to better team performance. Nevertheless, many human–robot teams exist primarily to perform vital tasks to society [16]. In many cases, better team performance is the desired outcome [17]. Moreover, social attraction among human team members has been linked to better team performance [5, 16]. This suggests that social attraction between team members and their robots could help facilitate better team performance with robots.

Second, prior research has focused on promoting social attraction to a robot by designing robots to appear more lifelike [18], including looking and responding as if they are really alive. This approach is valid and especially important in the context of the home or social robots for entertainment (i.e., robot pets). However, for work robots — robots used primarily for work-related tasks —making them more lifelike might not be possible nor always desirable. Work robots are often designed solely for task purposes and used by humans to perform hazardous and undesirable tasks [19]. Designing such robots to appear more lifelike could lead humans to avoid rather than rely on them [13]. Thus, we must find ways to enhance social attraction toward robots than making them more lifelike in their forms.

We propose a theoretical model, that is, team robot identification theory (TRIT), based on team identity theory (Fig. 1) for the theoretical investigation of robot identification at the team level. Team identification (hereinafter TI), the degree to which individuals view their team membership as a central part of their identity, is a strong predictor of team performance [20]. This is partly explained by an increase in affection among teammates [21]. Meanwhile, social attraction, one such type of affection, is crucial to understanding both teamwork and interactions with robots [11, 14, 15]. TRIT proposes that TI in human–robot teams leads to better outcomes by promoting affection between humans and robots. The present study describes affection in the form of social attraction.

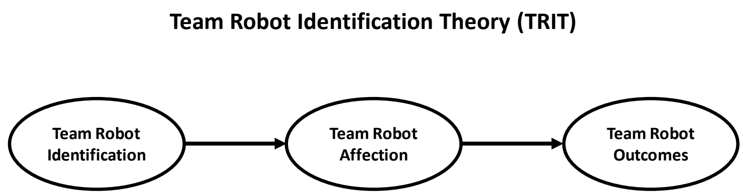

Fig. 1. Team robot identification theory framework

To empirically examine TRIT, we studied the impacts of TI and social attraction of humans toward their robots on the performance and viability of teams working with robots. To accomplish this objective, we conducted a study involving 60 participants in 30 teams working with robots, using a between-subjects (TI vs. no TI) experimental design. Results indicate that TI increased social attraction to robots, team performance, and viability in human–robot teams. The social attraction toward robots mediated the positive impacts of team performance and viability. These results provide new insights into promoting performance in teams working with robots.

This study has several contributions to the literature. First, we empirically examined a theoretical rationale—in the form of TRIT—that explains why TI through social attraction can facilitate better performance in human–robot teams. Although most scholars would agree that performance in such teams is an important topic, it remains vastly unexplored. Therefore, a theoretical and empirical examination of this topic is likely to advance our current understanding of TI and social attraction's impacts on actual team performance. Moreover, given that teamwork with robots is increasingly more critical [1], TI should be a key to understanding teamwork involving robots.

Second, this paper contributes to the literature on social attraction to robots. Scholars have long sought to identify factors that promote social attraction to robots [14, 22, 23]. Although much progress has been made, researchers have not investigated the role of TI.

Recent studies have highlighted potential identification problems in work teams using robots [24, 25]. Robots in teams decrease a shared identity among human teammates [25]. The findings were explained by shared identity, such that humans perceive robots as out-group members, but they fail to identify robots as part of their team [24, 25]. However, the extant literature also evidenced that strengthened TI in human–robot teams potentially benefits such teams by promoting positive perceptions, such as social attraction and trust in robots [2, 26]. These findings suggest that the promotion of TI by highlighting a common identity, including both robots and humans, would overcome the negative consequences of adding robots into work teams. In this way, this study seeks to contribute to the prior literature on a shared identity with a robot by examining the role of TI in enhancing social attraction and team outcomes. Thus, in the present research, we theorize and find evidence that TI plays a significant role in explaining social attraction to robots. As a result, we highlight TI as a new factor facilitating social attraction. Unlike previous factors, TI does not require that robots be designed to be more lifelike, making it more appropriate for work robots.

Finally, this study extends the research on social attraction to robots by demonstrating its performance benefits. Previous researchers have found that social attraction to robots leads to better interactions, but they have stopped short of examining team performance. This study expands the research by highlighting the vital role of social attraction in promoting better human–robot team performance.

In the following sections, we review several bodies of literature that informed and motivated our research. First, we provide a literature review on social attraction toward robots and how this research has evolved. In doing so, we highlight the absence of research directed at examining the implications of social attraction to robots concerning team performance. Then, we discuss the current literature on TI and its relationship to social attraction. Finally, we present our research model and its corresponding hypotheses.

2. Background

2.1 Social Attraction toward Robots

Social attraction toward robots has been identified as a vital element in understanding interaction quality between individuals and robots [14, 27]. Research on social attraction has been focused on understanding how to encourage people in building meaningful relationships with robots by eliciting natural interactions [28]. The social attraction has been identified as an essential facilitator of meaningful relationships between humans and their robots [11]. Scholars have studied social attraction of humans toward robots across a variety of settings, including education and training [29, 30], service [7, 14], and health care [31]. Social attraction toward a robot has been linked to people's willingness to adopt the robot [29], trust in the robot [14], and intention to personally purchase the robot [32].

The research on social attraction and robots has focused on promoting social attraction to increase the interaction quality between the user and the robot. Interaction quality represents the degree to which users are more motivated to engage with and enjoy using a technology [33]. The link between social attraction and better interactions is that individuals are often more motivated to engage with and enjoy interacting with things they are socially attracted to [23, 34]. Several studies have supported this assertion. For example, Cameron et al. [14] found that robots that apologize for their mistakes elicited higher levels of social attraction and intention to purchase the robot. Also, when a robot provided positive feedback regarding an individual's performance, users were more socially attracted to the robot and reported better interactions with it [30]. Niculescu et al. [23] determined that individuals reported better interaction with robots with higher voice pitches and displayed humor because they were more socially attractive. Similarly, users of robotic pets experienced better interaction when they were socially attracted to their pet robots [35]. Therefore, social attraction toward robots is critical to improving interaction quality between individuals and their robots.

Scholars have also examined ways to facilitate social attraction toward robots. Most of these efforts were focused on making robots more lifelike [18, 36]. These efforts include designing robots to be more natural in both behavior and appearance [37]. For instance, several studies manipulated eye gaze behavior to make it more natural and thus increase social attraction [36, 38]. Other studies have focused on making the robot more responsive to humans [18, 39]. This stream of research on social attraction is mainly conducted in the context of social robots, where individuals tend to like and feel less eeriness toward robots behaving and talking more like humans [34].

Despite these advances, several important areas need further development. We know little about whether social attraction can lead to better performance in human–robot teams. However, we know that social attraction among human teammates can lead to better team performance [40]. Besides, the current approaches to facilitating social attraction to social robots might be problematic for work robots. For example, designing robots to be more lifelike could lead humans to be less (vs. more) willing to employ them in dangerous situations [13]. Therefore, additional approaches need to be examined to foster social attraction toward robots.

Taken together, this study aimed to contribute to research on social attraction toward robots by examining it in the team context and proposing a more accessible way to enhance its impacts for teams working with robots.

2.2 Team Robot Identification Theory

This study proposes a theoretical model for teams working with robots based on TI. Specifically, we propose a way to promote social attraction toward robots by taking a social psychological approach—TI. Team identity is a shared identity among a group of individuals who belong to the same team [20].Meanwhile, TI is the degree to which individuals in a team feel attached to their team [41]. Theories of TI assert that the stronger a team member identifies with the team, the more the team becomes central to defining who they are as a person [42]. The stronger the TI, the more the team members see themselves as one cohesive unit [41]. This is used to explain why TI enhances social interactions among team members by promoting trust, cohesion, and goal attainment [15, 43]. It has also proved to be a strong predictor of social attraction in traditional human teams [44].

Researchers of HRI have also examined the impacts of a shared identity in teams working with robots [25, 45]. The literature has focused on understanding what happens when robots are included as part of the team process in work teams. Smith et al. [2] argued that failure to perceive a shared identity with a robot might result in negative attitudes toward the robot, including treating robots as competitors instead of teammates. Meanwhile, Savela et al. [25] viewed that robots can pose social challenges to work teams by degrading in-group identity among the human team members. They further found that when humans are perceived as the minority in their human–robot team, their group identity was reduced, suggesting potential negative consequences for work teams, including robots as part of team processes [25].

Meanwhile, shared identity in teams working with robots can also lead to positive outcomes. Generally, individuals show greater levels of preference toward in-group robots over out-group robots and humans [2, 24]. Research shows more evidence that team identity with a robot has led humans to have more positive perceptions and attitudes toward the robot [46]. When individuals were primed to believe that robots shared a common identity with them, they rated the robot as more humanlike, and they were more willing to interact with the robot [45, 47]. In another study, individuals who believed they shared a common identity with the robot engaged in more cooperative behavior [22]. Taken together, although the inclusion of robots to work teams can be problematic, research provides evidence that TI in such teams can result in positive consequences. Specifically, studies reporting positive effects of TI in teams working with robots suggest that promoting a shared identity with a robot can enhance positive perceptions toward robots and intention to interact with robots [48].

However, our current understanding of identification in teams working with robots cannot answer two critical questions. First, research lacks evidence for the causal link between TI and team performance. Despite TI's capacity to enhance positive perceptions toward robots that can contribute to team performance, whether a shared identity leading to social attraction promotes teams' performance and viability working with robots is still not empirically shown. Thus, this study seeks to address this issue by proposing a mediation effect of social attraction for TI's positive impacts on team performance and viability. Second, most research on identification with a robot has been conducted at the individual level but not at the team level. As Cameron et al. [14] reported, robots are likely to be included in teams with more than one individual. In this perspective, the literature of social psychology and HRI also implies that team interactions cannot be automatically translated from individual interactions and deserve their own right to examine the team level phenomenon [1, 2]. Thus, this research examines the impact of TI at the team level to contribute to the extant literature of group identity in human–robot teams.

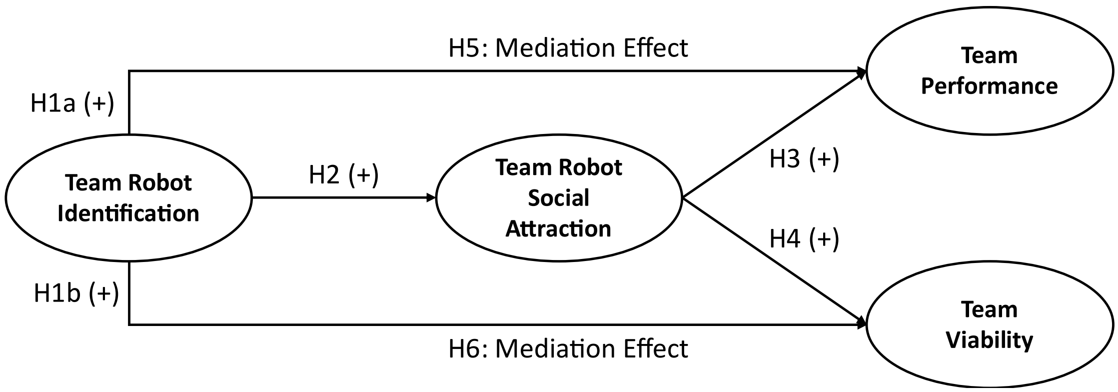

Fig. 2. Research model

To address the aforementioned issues, we propose a theoretical framework that highlights the link between TI with robots and outcomes of teams working with robots, where social attraction is a conduit to the relationship. Next, we present our research model based on TRIT (Fig. 2). The research model is one instance of the TRIT where affection is represented by social attraction. Moreover, it asserts that human–robot TI should increase team performance and viability by facilitating social attraction. The next section elaborates on the hypotheses in our research model and the theoretical arguments.

3. Hypotheses Development

Our first hypothesis posits that TI will lead to better performance and viability of teams working with robots. The traditional team research found TI to be effective in promoting team outcomes like performance and viability [43]. For instance, TI has been associated with better job engagement and satisfaction [43]. Scholars explained the impacts of TI through positive attitudes toward team members and cooperative behavior in teamwork [49]. A similar mechanism may contribute to teamwork with robots.

Although no prior researchers have examined the direct relationship between TI and outcomes for human–robot teams, existing HRI research indirectly supports this assertion [1, 47, 48]. For instance, individuals were more cooperative when interacting with robots sharing similar group identities [22]. Similarly, team members were more cohesive with other members who shared a common identity with the robot [47]. These results suggest that TI, including team members and robots, will contribute to better team outcomes. Thus, we hypothesized the following:

H1. TI in human–robot teams increases (a) team performance and (b) team viability.

Prior research on human teams has found that TI is positively related to social attraction [44]. TI can be described as the degree to which individuals feel a part of the team and view their team membership as a central part of their identity [50].Moreover, TI leads team members to minimize their differences and focus on their similarities through the self-categorization process. This, in turn, fosters likeability toward other team members [44]. Similarly, human team members are likely be more socially attracted to their robots in the presence of a stronger sense of TI.

A study of entertainment robots obtained some indirect evidence. Individuals were more socially attracted to their robot when they believed it shared a similar personality [36] or opinion to their own [11]. Similarity among team members is often used to explain the link between TI and social attraction in teams [42, 51]. Therefore, we believe TI in human–robot teams leads the team to greater social attraction levels.

H2. TI in human–robot teams leads such teams to have greater levels of social attraction toward their robots.

Across many settings, social attraction among teammates has been associated with better team performance [40, 52]. Social attraction increases team performance by improving interaction quality among team members [21]. This, in turn, leads to higher levels of engagement and cooperative behaviors [53]. This can manifest itself in greater agreement among team members or more effort exerted to accomplish team goals [54], all of which have been associated with better team performance [55]. As we noted earlier, research on HRI has also shown that social attraction toward one's robot can facilitate better HRIs [11]. Therefore, we believe that teams working with robots will perform better when team members are socially attracted to their robots.

Although no study yet has examined the relationship between team performance and the team members' social attraction to their robots, prior research offers indirect evidence. One study showed that individuals were more motivated to exercise when they liked their assistive exercise robot [31]. Another study examining explosive ordnance disposal teams found that team members who liked their robot also had better interactions with their robot [13].

Combining the findings from these studies with those from the teamwork literature, we see that social attraction to a person or a robot can lead to more engaged and cooperative interactions. We also know from the literature on teamwork that more engaged and cooperative interactions can improve team performance [53]. Based on the bodies of literature on both teamwork and HRI, we propose that better interaction between individuals and their robots, as a result of social attraction, should lead to better team performance.

H3. Humans' social attraction to robots in human–robot teams increases team performance.

Additionally, we believe that social attraction toward robots should increase team viability. Team viability represents the degree to which an individual wants to remain a member of the team [56]. We believe that individuals are more likely to enjoy their team experiences when individuals are socially attracted to their robots. This, in turn, should lead these individuals to want to remain a member of their team. Research supports the link between social attraction toward one's teammates and team viability [57].

Although no direct evidence links social attraction to one's robot with team viability, several studies have suggested that such a link exists. For example, better and closer interaction with a snack-delivery robot was associated with individuals wanting to maintain their relationship with that robot [7]. Another example is provided by Bickmore and Pickard [58]. They found that the degree to which individuals liked their virtual fitness-tracking agent determined how likely they were to maintain some long-term relationship with that agent. Thus, we hypothesized

H4. Humans' social attraction to robots in human–robot teams increases team viability.

Based on these arguments, we believe social attraction will mediate the impact of TI in human–robot teams on team performance and viability. That is, the effects of TI on performance and viability occur through social attraction. TI should lead to more social attraction, which in turn should lead to better performance and more viability.

H5. Humans' social attraction to robots in human–robot teams mediates the impact of TI on team performance.

H6. Humans' social attraction to robots in human–robot teams mediates the impact of TI on team viability.

4. Method

To study the effects of social attraction on team performance and viability, we conducted a between-subjects (TI vs. no TI) lab experiment.

4.1 Participants

We recruited participants from a national university in the United States and included 60 individuals in 30 teams. The mean age of the participants was 24 years (standard deviation [SD] = 5.88 years), and 32 (53%) were women. The participants were recruited individually and then paired randomly with another participant to be assigned to a team of two individuals and two robots. Upon completion of an experimental session, the participant received $20. Additionally, participants were informed that those in the first, second, and third performing teams would receive an additional $50, $20, and $10, respectively. Three teams were selected solely based on the task performance and were paid the additional payment after completing the whole experiment.

4.2 Robots

The robots used in the experiment were LEGO® MINDSTORMS® EV3 (Fig. 3) and were designed to be capable of gripping plastic water bottles. Participants controlled their robot using an infrared remote controller. We employed the robots created with Lego Mindstorms for several reasons. First, Mindstorms allowed researchers to design and program custom robots suitable to research questions and experimental manipulations. Specifically, we were able to program the robots' behavior to imitate essential tasks in real teams (e.g., grabbing, fetching, and releasing items from one place to another) [59]. Second, robots created with Lego Mindstorms were easily accessible and usable to our participants, eliminating unnecessary complexity in interacting with the robots. All participants reported having certain degrees of previous experience of using Lego before participating in our study. Lastly, several prior works on HRI and collaboration have validated the use and effectiveness of robots with Lego Mindstorms [29, 60].

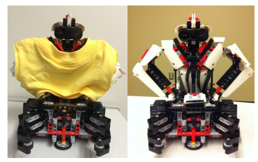

Fig. 3. Robot with (left) and without (right) a uniform

4.3 Experimental Task

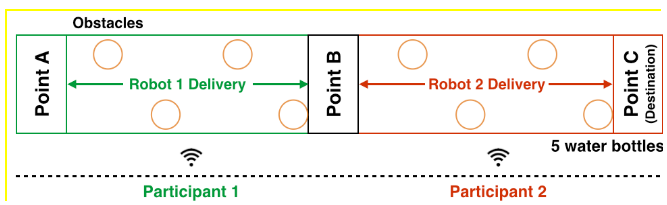

Fig. 4. Experimental task and setting

The task was to deliver five small water bottles from point A to point C via point B using their robots as quickly as possible (Fig. 4 for the task area layout). The task was designed to be a cooperative team activity. Team member 1, using his or her robot, picked up water bottles at point A and dropped them off at point B. Also using a robot, team member 2 picked up water bottles at point B and dropped them off at point C. The task was completed when five water bottles were moved from point A to point C. During the task, participants in the same team were allowed to talk and communicate verbally and non-verbally.

The task required the following rules. First, during the task, participants in the same team were allowed to talk to each other and communicate verbally and non-verbally. The communication between team members has no restriction. Second, participants were not allowed to touch the water bottles and were required to stay outside the robots' work area (which was within the green and red lines). Third, each robot could not move beyond its designated work area. For instance, team member 1's robot should not deliver water bottles beyond points A and B. Moreover, team member 2's robot could only go between points B and C and pick up water bottles from point B. As such, the task could not have been completed by any team member.

Our choice of the task was made based on the relevant studies in human–robot collaboration. First, several studies indicated that moving an object from one place to another is one of the most common and essential tasks currently benefiting from human–robot teams. For instance, human team members in bomb disposal operations deploy robots to a mission area, remove and move a target object, and recover the robots [13]. Moreover, urban search and rescue teams also perform similar tasks to save human casualties out of dangerous areas [61]. Second, the task should be cooperative, and team performance should depend on both team members. The sequential collaboration between two individuals with two robots was only achievable by both individuals putting a joint effort, such as communicating better ways to control the robots and coordinating the locations to drop off the bottles to minimize inefficiency [62, 63].

4.4 Manipulation

TI was manipulated by varying the degree of activities emphasizing a common team identity. A common team identity minimizes feelings of differences and maximizes feelings of similarity, thus facilitating social attraction [15]. All team members and their robots in the treatment condition wore team uniforms. Participants chose the color (i.e., yellow or blue) of the team's uniform. The robots' uniforms were identical in form and color to the participants' but were made from 6-month infant clothes because of the robots' size. Second, participants created a unique team name for the team. Such manipulations were based on the idea that visual cues (e.g., colors and uniforms) and team names reinforce the team identity (e.g., sports teams) [64].

However, teams in the control condition performed the experimental task without wearing uniforms or creating a team name.

To ensure whether our manipulation of TI is successful, we measured perceived TI, which captured the degree to which individuals identified themselves with their team, as a manipulation check. The construct was measured using a 5-point scale adapted from Brown et al. [50], ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The scale consisted of four items, including "I was happy with being identified as a member of this team" (Cronbach's $\alpha = 0.92$).

4.5 Procedure

Participants signed up for a session using an online sign-up sheet. The sign-up sheet was fully anonymized, so they do not know who their teammates would be. Each participant was randomly assigned to a team of two people and two robots. Moreover, each team was randomly assigned to a treatment condition (TI) or control condition (no TI).

Upon arrival, participants were greeted and given a brief instruction about the study along with the consent form. After completing the consent form, participants were asked to fill out a short pre-questionnaire about their demographic information. Then, they were given written instructions on the experimental task and how to use their robot. Afterward, they watched a video depicting the task and how to operate the robot. After the instructions, participants who were assigned to the treatment condition put the uniforms on themselves and their robots and provided their team names to the experimenter. Meanwhile, participants who were assigned to the control condition were guided directly to the next procedure.

After undergoing instructions and treatments, participants were guided to another room to begin the task. Before the timed task was conducted, all teams conducted a 2-minute training session. This training involved two untimed trial runs during which participants were allowed to try out various movements with their robots. During the trial runs, teams could practice delivering all five water bottles.

After the training, the teams performed their actual timed task. The experimenter timed each team's performance using a stopwatch. The task was completed after the fifth water bottle was delivered to point C. Participants were notified of their team performance, but the performance of other teams in the experiment was not revealed to anyone until the whole experiment was finished. When participants were finished, they returned to the survey room to complete a post-questionnaire. After completing the final survey, they were debriefed, paid, and dismissed.

4.6 Measures

Note that all psychometric measures in this study, except for team performance that was measured objectively, were captured at the team level construct. We obtained team level constructs by aggregating individual team members' responses into average values. The aggregation is typically justified with an intraclass correlation coefficient (ICC) greater than 0.1 [65]. The ICC of TI was 0.4, which justified the aggregation to the team level.

4.6.1 Robot Social Attraction

We measured social attraction using an index of six items adapted and combined from Takayama et al. [11]. Participants were asked to answer a question, "How would you describe the robot?" on robot characteristics, such as cheerful, cooperative, friendly, happy, kind, and warm, based on a 5-point scale from 1 (*strongly disagree*) to 5 (*strongly agree*). The measurement was reliable (Cronbach's $\alpha = 0.89$) and justified for aggregation (ICC = 0.46).

4.6.2 Team Performance

We measured the performance by the time in seconds it took the team to deliver the last water bottle to point C. The time was measured between when robot 1 began to move and when robot 2 dropped the fifth water bottle at point C. The shorter the time was, the better performance the team recorded. Team performance measured in time has been employed and validated by prior works in various fields examining interactions with robots [66].

4.6.3 Team Viability

Team viability captured the degree to which team members believe that their team would continue to perform well in the future. Team viability has been validated to indicate whether team members want to remain in their team and thus the team's longevity [56]. We measured team viability using an index of five items adapted from Gardner and Kwan [52], based on a 5-point scale. An example item is "This team including the robots would perform well together in the future" (ICC = 0.53; Cronbach's $\alpha = 0.95$).

4.6.4 Control Variables.

We added participants' prior experiences in fields related to HRI. Three items were separately asking the degree to which an individual participant perceives their levels of knowledge and expertise in computing in general, robotics, and artificial intelligence. The measures were based on a 5-point scale.

5. Results and Hypothesis Testing

5.1 Manipulation Check

To ensure that the treatment effectively manipulated TI, we measured perceived TI using an index of six items adapted from Brown et al. [50]. Results of a t-test showed that the teams in the treatment condition had a significantly higher team average of TI ($M = 4.08$, $SD = 0.41$), than teams in the control condition ($M = 3.67$, $SD = 0.56$, $t(28) = 2.26$, $p < 0.05$).

5.2 Construct Reliability And Validity

We assessed the convergent and discriminant validity of the model constructs in multiple ways. First, a factor analysis with the latent variables in our model has been performed (Table 1). Except for the second item of social attraction, all items demonstrate the model variables' discriminant and convergent validity [67]. Despite the low loading of −0.24, the second item of social attraction was kept because of the high Cronbach's alpha of the variable, indicating that the overall items consistently capture the construct. Additionally, correlations among the model constructs were tested to ensure discriminant and convergent validity (Table 2).

Item	1	2	3
Knowledge on Computing	**0.83**	0.03	0.02
Knowledge on Robotics	**0.92**	0.13	-0.04
Knowledge on Artificial Intelligence	**0.94**	0.04	-0.01
Social Attraction 1	0.08	**0.73**	0.13
Social Attraction 2	−0.27	−0.24	0.42
Social Attraction 3	0.14	**0.79**	0.26
Social Attraction 4	0.18	**0.88**	0.21
Social Attraction 5	−0.02	**0.96**	0.10
Social Attraction 6	−0.04	**0.94**	0.02
Team Viability 1	0.05	0.11	**0.79**
Team Viability 2	0.05	0.11	**0.95**
Team Viability 3	0.00	0.14	**0.92**
Team Viability 4	0.01	0.36	**0.85**
Team Viability 5	−0.06	0.25	**0.89**

Principal Component Analysis was used for extraction. Rotation was done using Varimax with Kaiser Normalization.

Table 1. Factor loadings of variables in the research model

To ensure the convergent validity of the measures, we calculated the average variance extracted (AVE) square root. All variables indicated values greater than 0.50, the threshold for evidence of convergent validity [67]. The AVEs for social attraction and team viability were 0.63 and 0.78, respectively. Meanwhile, the discriminant validity of the variables was assessed by ensuring that correlations among the variables were below the square root of the AVEs.

Constructs	M	SD	1	2	3	4	5	6	7
1. Knowledge on Computing	2.50	0.85	–						
2. Knowledge on Robotics	1.97	0.60	0.64**	-					
3. Knowledge on Artificial Intelligence	2.05	0.58	0.65**	0.85**	-				
4. Team Identification	0.50	0.51	−0.28	0	−0.03	-			
5. Social Attraction	3.23	0.51	0.08	0.15	0.05	0.39*	**0.79**		
6. Team Viability	4.35	0.71	0.03	−0.01	0.01	0.34	0.40*	**0.88**	
7. Team Performance	258.13	53.82	−0.21	−0.11	−0.16	−0.37*	−0.37*	−0.47**	-

M = mean, SD = standard deviation, * p < 0.05, ** p < 0.01(2-tailed), Team Identification was coded binary (0 = control condition, 1 = team identification condition). Diagonal values = the square root of the AVE

Table 2. Descriptive statistics and correlations among variables

5.3 Hypothesis Testing

The hypothesis testing was conducted through a series of hierarchical linear regressions for H1–H4 and the causal steps approach for H5–H6. Analyses for H1–H4 examined the direct effects of robot identification and social attraction on team performance and team viability, respectively. Additionally, the analyses for H5 and H6 examined the mediation effects of team robot social attraction on the relationship between team robot identification, performance, viability, as dependent variables.

H1 posited the positive impacts of TI on team performance and viability. Results of hierarchical linear regressions show that team performance is higher for teams in the TI condition (M = 238.65 seconds, SD = 26.44) than teams in the control condition (M = 277.62, SD = 67.00, B = −52.76, p < 0.05). Moreover, team viability is higher for teams in the TI condition (M = 4.59, SD = 0.56) than teams in the control condition (M = 4.11, SD = 0.77, B = 0.57, p < 0.05). Therefore, both H1a and H1b were supported. Similarly, H2, which stated that TI would increase social attraction toward robots, was supported. Results show that social attraction toward robots is higher in teams with TI (M = 3.43, SD = 0.52) than in teams without such treatment (M = 3.03, SD = 0.44, B = 0.45, p < 0.05). Table 3 provides details of the results.

Dependent Variable	Team Performance				Team Viability				Team Robot Social Attraction			
	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI
Constant	277.08***	35.45	204.06	350.09	4.52***	0.50	3.49	5.55	3.24***	0.35	2.52	3.96
Control Variables												
Knowledge on Computing	−28.77	15.65	−61.01	3.46	0.21	0.22	−0.25	0.67	0.15	0.15	−0.17	0.47
Knowledge on Robotics	24.72	30.09	−37.26	86.70	−0.20	0.43	−1.07	0.67	0.23	0.30	−0.38	0.84
Knowledge on Artificial Intelligence	−10.74	31.32	−75.25	53.77	−0.01	0.44	−0.92	0.90	−0.29	0.31	−0.93	0.34
Main Effects of Team Identification												
Team Identification	−52.76*	19.45	12.69	92.82	0.57*	0.28	−1.14	−0.01	0.45*	0.19	−0.85	−0.06
R^2	0.27				0.15				0.22			
df	4				4				4			

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$
Team identification was coded binary (0 = control condition, 1 = team identification).

Table 3. Results for H1–H2

As hypothesized in H3, social attraction toward one's robot is positively associated with team performance (B = −39.98, $p < 0.05$). The time taken to complete the task was shorter in teams with higher levels of social attraction. As hypothesized in H4, social attraction toward one's robot is also significantly related to team viability (B = 0.58, $p < 0.05$). H3 and H4 were fully supported, and the results are shown in Table 4.

Dependent Variable	Team Performance				Team Viability			
	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI
Constant	417.74***	69.93	273.72	561.75	2.55*	0.93	0.64	4.45
Control Variables								
Knowledge on Computing	−12.80	15.33	−44.37	18.78	0.04	0.20	−0.38	0.45
Knowledge on Robotics	26.76	31.95	−39.04	92.56	−0.27	0.42	−1.14	0.61
Knowledge on Artificial Intelligence	−24.81	33.26	−93.32	43.69	0.18	0.44	−0.73	1.09
Main Effects of Team Robot Social Attraction								
Team Robot Social Attraction	−39.98*	19.25	−79.62	−0.33	0.58*	0.26	0.05	1.10
R^2	0.19				0.17			
df	4				4			

*: p < 0.05, **: p < 0.01, ***: p < 0.001

Table 4. Results for the impact of team robot social attraction (H3 and H4)

H5 and H6, which state that the effects of TI on team performance and viability should be mediated by social attraction, were also supported. Both mediation tests were based on a causal steps approach [68]. According to the approach, observing a mediation effect has three steps. First, an independent variable (i.e., TI) should predict the dependent variable (i.e., team performance and team viability). Second, the mediator variable (i.e., team robot social attraction) predicts the dependent variables. Third, when controlling for the mediator variable, the impact of the independent variable becomes non-significant for full mediation or less significant for a partial mediation effect [68].

H2 provided evidence that TI was positively related to social attraction toward robots. H3 and H4 provided evidence that social attraction was positively associated with performance and viability. As an indication that H5 is supported, the main effect of TI on team performance became insignificant when social attraction was included (B = −42.35, p = 0.06). H6 posited a mediation effect of the social attraction of robots between TI and team viability. As shown in

Table 5, H6 was supported in that the effect of TI on team viability became insignificant when the social attraction was included (B = 0.38, p = 0.21).

Dependent Variable	Team Performance				Team Viability			
	B	SE	LLCI	ULCI	B	SE	LLCI	ULCI
Constant	351.38***	74.17	198.30	504.46	3.14**	1.03	1.02	5.26
Control Variables								
Knowledge on Computing	−25.39	15.84	−58.08	7.31	0.15	0.22	−0.31	0.60
Knowledge on Robotics	30.03	30.28	−32.46	92.52	−0.30	0.42	−1.16	0.57
Knowledge on Artificial Intelligence	−17.46	31.69	−82.87	47.95	0.12	0.44	−0.79	1.02
Effects of Team Robot Social Attraction								
Team Robot Social Attraction	−22.93	20.15	−64.52	18.64	0.43	0.28	−0.15	1.00
Main Effects of Team Identification								
Team Identification	−42.35	21.39	−1.79	86.50	0.38	0.30	−0.99	0.23
R^2	0.31				0.23			
df	5				5			

*: p < 0.05, **: p < 0.01, ***: p < 0.001

Table 5. Results for H5 and H6

6. Discussion

This study aims to identify ways to facilitate TI and social attraction to robots and examine their impacts on team performance and team viability in human–robot teams. We proposed a theoretical framework for examining TI and social attraction in teams working with robots to accomplish this goal. Our results can be organized around three overarching findings. First, TI in human–robot teams leads to more social attraction, better performance, and more team viability. Second, social attraction also leads to better performance and more team viability.

Third, social attraction mediates the impact of TI on team performance and viability. These results have implications for theory and design, which we will discuss next.

6.1 Implications for Theory

First, we provide a theoretical framework, that is, TRIT, which asserts that TI in human–robot teams increases performance and viability through social attraction. Results of our study offer empirical support for TRIT. In doing so, this study advances our current understanding of human–robot teams and the factors that drive their performance. This topic is vital because our society is increasing its reliance on such teams and because they often perform life-saving work in communities. That being the case, more research is needed to explore this topic further. This research could employ TRIT as the basis to examine whether TI in human–robot teams can facilitate more trust, thus promoting outcomes like performance. Additionally, future research could explore moderators that might alter the relationship between TI and affect responses in human–robot teams.

Second, this study extends the research on social attraction to robots by identifying social attraction as a key predictor of both performance and viability in human–robot teams. Prior research on social attraction in human–robot relationships has typically treated social attraction as an outcome variable [11]. However, prior research failed to examine its implication for team performance despite the potential implications of social attraction for team processes and outcomes. In contrast, our findings suggest that social attraction is vital for the success of teams working with robots. It increased not only team performance but also team viability. This study's findings have significant implications for research on teams working with robots, in that social attraction can promote both objective task performance and subjective assessment of the interaction quality within teams.

Third, we found that TI increased social attraction and subsequent team outcomes in teams working with robots. These findings demonstrate that TI is an effective way to foster positive perceptions toward robots, which TRIT argues. Moreover, TI does not require robots to be more lifelike; therefore, promoting social attraction in teams with work robots might be more appropriate. This finding can be used as a guide for future research on social attraction toward robots. Future research could also examine other team-oriented factors to determine whether they foster social attraction toward robots. For example, individuals often set high expectations for others [69]. It would be interesting to know what would happen if a robot violated these expectations. This might lead to less social attraction to robots.

Finally, this study provides evidence that sharing a common identity with a robot and one's feelings toward the robot can have a similar effect on team performance. This study only examined the effects of TI and social attraction. However, team interactions and relationships between humans and robots could be just as complex and influential as such interactions and relationships. Research suggests that interactions with robots at the team level are also subjects of social psychology and warrant investigations considering many facets in HRI as in human–human interaction [1, 2]. Therefore, future research should examine whether other factors derived from such interactions and relationships (e.g., norms, obligations, and communication quality between humans and robots) are important for promoting outcomes, such as performance and viability.

Research provides evidence that TI can be a double-edged sword to teams working with robots. Depending on team composition (i.e., the ratio of robots to humans in a team), TI may yield different results to human–robot teams [24, 25]. When individuals are the minority in human–robot teams, the inclusion of robots in such teams may hamper in-group identification among human teammates, thereby decreasing team performance and viability [25]. Our results contribute to such findings by showing that the inclusion of robots can be harnessed to enhance team performance and teammates' perceptions on team viability by promoting TI in such teams. Specifically, once humans admit robots as an integral part of a team and successfully identify with robots and humans as a whole, the adverse effects of robot inclusion on group identity in human–robot teams can be prevented or at least reduced.

6.2 Implications for Practice and Design

Leaders and managers of teams working with robots should be aware of the importance of making their team members feel that their robots are socially attractive. Our results highlight the importance of TI and social attraction in teams working with robots. Organizations employing human–robot teams should provide opportunities for people to build TI with their robots. For instance, team members should undergo a training session designed to create a shared identity between humans and robots. We recommend that such training be implemented before team members start tasks with the robots.

Another approach to address this issue could be viewed as implications for design. Robots could be designed to highlight group membership by providing visual cues, such as painting the human–robot team's name on the robot. Another example is using common color schemes in the uniform and the robot to emphasize team membership to highlight common visual aspects between robots and team members. These approaches do not require making the robot more lifelike, which potentially leads to negative feelings toward robots that are humanlike [70].

6.3 Limitations and Future Research

This study is not without limitations. First, this study was conducted in a laboratory setting with a physical team task, where individuals were required to work together to accomplish a team goal. The task and the experimental setting were carefully chosen to replicate the tasks that actual human–robot teams have actually performed currently. However, how our findings unfold in different settings and tasks is left unanswered [22]. One example is knowledge-based collaborations increasingly performed by teams working with robots [1]. The findings presented here provide an opportunity for future studies to examine the impact of TI on human–robot teams in alternative tasks and settings. Given that TRIT offers some theoretical avenue to explore the impact of TI on affective relationships with robots, future research may further investigate its implications for team performance in objective and psychological dimensions.

Second, human–robot teams in this study consisted of two individuals and two robots. Although our findings demonstrate robust effects of TI in teams with such a structure, teams in different compositions of humans and robots may undergo psychological processes and experience TI effects that our findings may not explain. As discussed earlier, the human-to-robot ratio seems to be essential in turning TI into performance gains [1, 25]. Currently, TRIT is mainly focused on the team level phenomena of TI. More complex compositions of human–robot teams may engender a wide variety of psychological effects, such as subgroup formation and perception of minority [25], all of which provide boundary conditions for the impacts of TI in future research.

7. Conclusion

Although group identity and social attraction have been viewed as critical factors to understanding better interaction quality with robots, research has not focused on whether these constructs promote the effectiveness of teams working with robots. We proposed a theoretical framework and empirically examined the impacts of TI and social attraction toward robots on team performance and viability to address this issue. We reported results from a lab-based experiment with 30 teams working with robots. Results indicate that social attraction toward robots improves team performance and team viability and mediates the impacts of TI on both team outcomes. This study contributes to the expanding research on a shared identity with robots by highlighting the importance of social attraction and TI in teams working with robots and their effectiveness.

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