Raising Stars: Influences of Robotic Peer Liking on Emergent Leadership

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***Abstract*—Emergent leadership in teams is known as a special type of informal leadership that has unique benefits. Because this type of leadership is developed organically from within the team and depends on peer liking, it is highly challenging to encourage. In this work, we explored the possibility of leveraging robotic social behavior to facilitate the emergent of leadership in a team. We evaluated whether a robot displaying explicit peer liking towards one of the team members would be sufficient to facilitate leadership by that participant. Two stranger participants were asked to engage in a search task together with a robotic dog who either presented peer-liking behavior toward one or both of the participants during the opening encounter. Our findings suggest that the robot's peer liking led the "Liked" participant to report higher sense of leadership and higher sense of responsibility over the task. Behavioral measures also indicated that the "Liked" participant managed the team's performance. We suggest that integrating a robot into human teams presents a unique opportunity to facilitate team dynamics without the need to impose a structure on the team from the outside.**

***Index Terms*—Interaction shaping robots, emergent leadership, opening encounters, peer liking, informal leadership**

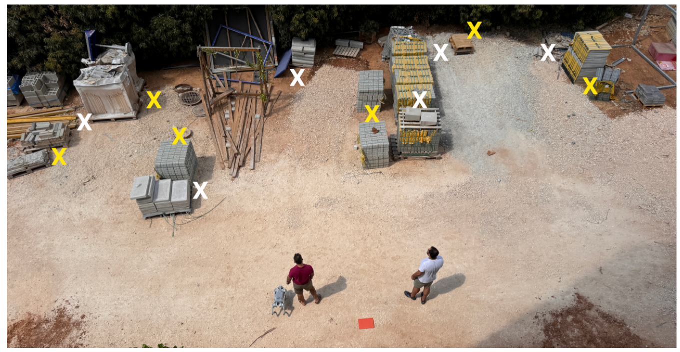

Fig. 1. Experimental settings and the robot's positions in the *Unequal Liking* condition. White numbers indicate cube locations with the relevant symbols; yellow numbers indicate cube locations without the relevant symbols. The "task sheet" for managing the task is placed behind the participants

I. Introduction

In recent years, there has been a growing interest in the impact of robots on the dynamics between humans (e.g., [1]–[10]). The possibility of shaping and forming human interactions through robots has been demonstrated in different contexts [3], [7], [11] and with different types of robots [3], [4], [6], [8], [9], [12]. These studies indicated that robots can impact conflict resolution [13], enhance humans' interpersonal evaluation [6], encourage more balanced participation in group activities [9], and mitigate emotional challenges by reducing awkwardness between people [7], [8]. An important aspect of human dynamics that has been less studied in the context of interaction with robots is emergent leadership in teams.

Teamwork is an important type of human–human interaction [14]–[16] that involves a group of interdependent individuals who act together to achieve a common goal [17], [18]. It is a dynamic process in which flexible cognitions, behaviors, and attitudes should be used to successfully perform collaborative tasks [14]. Teamwork is known to have various benefits, including efficient problem solving [18], skill development [19], [20], enhanced motivation [16], [20], and decreased burnout [16]. The quality of teamwork is known to heavily depend on the team's leadership [14], [21]–[23]. Prior work in psychology indicates that by taking responsibility and focusing on both the team's goal and needs, leaders can significantly facilitate teamwork [22], [24], enhance team cohesiveness [25], and motivate the positive behavior of team members toward each other [26]. The human–robot interaction (HRI) literature has already indicated the advantages of integrating robots into teams [27], [28], and specifically their relation to leadership, ranging from the positive effects of robots acting as team leaders [29], [30] to the impact of integrating robots as leader assistants [31]–[36].

Traditionally, leadership studies, from both the psychology and HRI domains, have focused on formal leaders who have explicitly been given responsibility for the team (also known as vertical leadership [22], [37], [38]). These leaders typically prioritize power over enhancing inner-team processes and, as a result, miss out on some of the benefits associated with high-quality team leadership [39]. In recent years, there has been a growing interest in informal leadership, where no direct responsibility is formally assigned to any of the team members [22], [37]. This type of leadership, also known as emergent leadership, is based on social processes within the team, where team members informally accept one of the members (who does not have a formal status) as their leader [14], [40], [41]. Emergent leadership is known to have various unique benefits, including an enhanced team cohesiveness and social support among team members [42], [43], enhanced sense of trust among team members [44], and increased commitment to team goals [45], which typically improves team performance [45], [46]. It has also been suggested that robots can be programmed to identify emergent leadership processes and estimate the leader that would maximize team performance [47].

Several studies have explored the development of emergent leadership and identified factors related to the team members' personality traits as the main factor contributing to the emergence of leadership (for a recent review, see [21], [48]). One factor that has stood out as encouraging the emergence of leadership is peer liking [49]. Peer liking refers to the extent to which peers favor a specific team member in interpersonal interactions [50]. Being liked by others typically leads to social power and the development of various relationships [51]. This suggests that informal leadership, with its unique benefits, will not necessarily emerge in any team. Moreover, it cannot be easily encouraged because it depends on the personalities of the team members and their liking of each other. In this context, the integration of robots in teams presents an unexplored opportunity to facilitate emergent leadership. It is possible that integrating a robot that displays peer liking toward a specific team member could facilitate the informal leadership of that selected team member.

Peer liking in robots can be easily designed by applying simple robotic behaviors [9], [52], [53]. Among these behaviors, a robotic preference exhibited at the beginning of the interaction can have a powerful impact [54]. It is already well established that the opening encounter with a robot influences the valence and quality of the interaction that follows [2], [54]–[59]. A positive opening encounter with a robot typically leads to an overall positive experience and enhances the perception of warmth that lasts throughout the interaction [2], [54], [59]–[61]. This is attributed to a psychological mechanism that translates positive social cues in the opening encounter into a sense of belonging that sets the social foundations for subsequent interactions [62], [63]. Coupled with the understanding that emergent leadership is highly impacted by social cues [64], the social power of opening encounters suggests that a robot's peer liking displayed in the opening encounter can be leveraged to facilitate the emergence of informal leadership.

In this work, we evaluated the possibility of integrating a robot into a human–human team in a way that would facilitate the emergence of leadership. We designed the robot to demonstrate peer liking in the opening encounter of a team interaction that involved a collaborative search task. The team consisted of two (stranger) participants and a robotic dog who were asked to decipher a code that consisted of unfamiliar symbols. The translation of the symbols could be found on cubes spread across an outdoor area (see Figure 1). We evaluated whether the robot's peer liking displayed at the opening encounter towards one (rather than both) of the participants would facilitate emergent leadership. We tested whether the explicit preference of one of the participants would facilitate that participant's tendency to lead the task and take over responsibility for task performance.

II. Related Work

Relevant prior research has evaluated how robots can shape human-human dynamics, the impact of a robot's preference for one participant in human–human–robot interactions, and leadership in HRI.

A. Robots shaping human–human dynamics

Various studies have indicated that robots can easily impact and even shape interactions between humans (for a recent review, see [1]). Social robots have been shown to serve as facilitators, promoting collaboration between people [65]–[67], enhancing the inclusion of humans in an interaction [9], [12], [28], [68], [69], mediating conflicts between humans [13], [52], and influencing emotional aspects of the interactions between humans [7], [8], [11]. For example, Rifinski et al. [6] explored the impact of a non-humanoid robot on human–human interactions in conversational contexts. They found that minimal gaze and leaning gestures towards the speaker enhanced participants' interpersonal evaluation of each other. A similar robotic behavior was employed by Erel et al. [5], who demonstrated that when a person shares a challenge in a human–human interaction, a simple peripheral robot can enhance the emotional support provided by the other (human) participant in the interaction. The peripheral robotic modeling of the desired supportive and attentive behavior resulted in an interaction that involved a high sense of empathy and overall positive human–human interpersonal relationship. Likewise, Zhang et al. [70] found that a humanoid robot can facilitate meaningful connections between strangers. Participants were asked to stay in a waiting room while a conversation facilitator was introduced. A robotic facilitator was found to be effective in making participants converse on deep and intimate personal topics. Integrating a robot into human–human interactions has also been shown to lead to negative effects, impairing the interpersonal relationships between people [71]–[73]. For example, Sebo et al. [74] found that in a team collaborative task, being the only team member who can communicate with a robot leads that person to feel less included and makes it less likely that their ideas are incorporated into the group's final decision.

The above studies indicate the wide range of effects robots can have when integrated into human–human interactions. We extend this line of work by testing the possibility that a robot can shape emergent leadership in a team of two strangers when neither of them is formally assigned as the team's leader.

B. Impact of a robot's preference of one participant in human–human–robot interactions

A special case of robots shaping human–human dynamics concerns the impact of a robot preferring one participant over another in interactions that involve more than one human. Previous studies have indicated both positive and negative effects from a robot's explicit preference [9], [53], [73], [75]. A few studies have indicated that a robot can lead to a more balanced human–human dynamics by preferring a specific participant [9], [52], [76]. For example, Tennet et al. [9] presented a robotic microphone designed to promote participants' engagement in decision-making discussions in three-person teams. By performing simple turn gestures towards a specific participant, the robot indicated its attentiveness toward that participant in an attempt to encourage the participant to take a more active the part in the discussion. The simple gestures toward the more passive participant in the conversation led to increased engagement and more balanced human–human dynamics. Similarly, Neto et al. [68] demonstrated the potential of leveraging robots for enhancing inclusion in groups of children with mixed visual abilities. In the study, groups of three children (two sighted and one visually impaired) participated in decision-making activities. A robot that was integrated into the interaction expressed its preference for the least active speaker. The results indicated that the robot's direct preference balanced speaking time in groups in which one child spoke significantly more than others.

Robotic preference has also been shown to result in negative effects. Jung et al. [73] indicated that a robot's liking of one team member could impair the interpersonal relationships between the people in the team. In this study, participants performed a collaborative task of building the tallest tower possible from wooden blocks that they received from a robotic arm. Despite the collaborative nature of the task, when the robotic arm allocated the blocks unequally (i.e., gave one participant more blocks than the other), the two participants reported lower satisfaction with team relationships compared to teams in which the blocks were distributed equally. Expanding on this work, Claure et al. [75] developed an algorithm for a robot in human–robot teams that progressively favored "stronger" players (those who performed better). They showed that the robot's preference negatively impacted its perception.

These studies indicated that a robot's preference for one group member can impact group dynamics and the robot perception. We extend this line of work by testing whether a robot's preference can also be leveraged to encourage a selected team member to become the informal leader of a team.

C. Leadership in HRI

Previous work has investigated different aspects of leadership in HRI, including contexts in which the robot is designed to lead humans and contexts in which the robot follows a human leader [77]. These studies have focused on the acceptance and impact of robots as leaders [29], [30], [78]–[81] and the possibility of alternating leadership between human and robot team members to maximize team performance [82]–[85]. A few studies have also tested the impact of robots that follow human leadership [47], [79], [80], [86], [87]. These studies indicate that when robots follow human leadership, the leaders are perceived as more persuasive [80], the team performs better [79], [86], and team members report a greater sense of safety [88]. A slightly different perspective was taken by Kwon et al. [47], who introduced an algorithm that can identify leader–follower dynamics in human teams. They suggested that their algorithm can be leveraged by robots to signal that there is a need to switch leadership in order to reach better outcomes.

We extend these studies on leadership in HRI by testing whether a robot's peer liking, presented at the beginning of the interaction, can facilitate informal leadership.

III. Method

To determine whether a robot can encourage emergent leadership by demonstrating peer liking towards one team member, we designed a team search task. Two participants (with no previous acquaintance) were asked to perform the search task together with a robotic dog. To display peer liking, the robot performed a positive opening encounter either toward only one of the participants, showing a clear preference for and liking toward that participant, or toward both participants. We therefore evaluated emergent leadership under the following two *Robotic Conditions*: 1) *Unequal Liking*: the experimental condition, in which the robot's positive opening encounter indicated the robot's preference for and liking of one of the team members; 2) *Equal Liking*: the baseline condition, in which the robot's positive opening encounter did not indicate a preference for any of the team members.

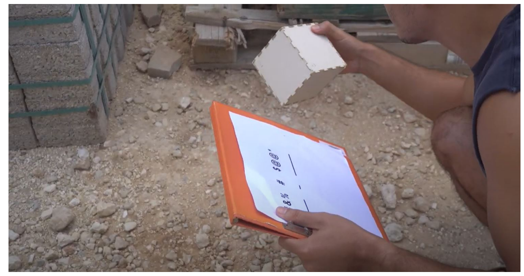

Fig. 2. "Task sheet" used for managing the task, which provides the set of symbols that must be decoded.

A. Search task and robot

1) Search task: In the search task, participants were given a "task sheet" with a set of symbols representing a code that the participants were asked to decipher. The code comprised eight unfamiliar symbols that the participants had to translate into letters in order to read the sentence they represented (see Figure 2). Participants were then informed that the translation of each symbol into a letter could be found on cubes that were spread across an open area outside. They were also informed that there were various symbols on each cube, and that some of them were relevant for the code while others were not. We intentionally chose an open area with many items to create a suitable environment for a search task (see Figure 1). Twelve cubes were spread across the open area. On each of the faces of each cube apart from the bottom one, there was an expression that indicated which English letter a symbol represented (for example, symbol "*=D" indicates that "*" represents the letter "D"). To increase the task difficulty, only six cubes had symbols relevant to the code (four cubes included one relevant symbol, and two cubes included two relevant symbols, resulting in eight different English letters). The four word code "!#&% # $@@* *#;" translates into "Have a good day" when successfully deciphered. It took several iterations to develop a task that was complex enough to require the mutual dependence and communication between team members that would enable the emergence of leadership.

2) Robot and gesture design: We used the Unitree Go1 robot, a small 15 kg quadruped with 12 degrees of freedom (see Figure 3). The decision to use this particular robot was motivated by the possibility of aligning the robot's behavior

Fig. 3. Robotic dog used in the experiment

with participants' pre-existing experiences with real dogs, minimizing the novelty associated with the HRI context. The robotic dog also allowed us to avoid social complexities related to language and speech tone [54], [89], [90]. The robot was operated remotely from within the building using the Wizard-of-Oz method, where the researcher controlling the robot was out of sight [91], [92].

To design the robot's demonstration of peer liking in the opening encounter, we used a robotic behavior that was designed and validated to indicate a positive greeting in previous studies using robotic dogs [54], [90]. The robot walked towards the participants and when it reached a distance of approximately 65 cm from them, it positioned itself in front of the participants: either directly in front of one of the participants (*Unequal Liking* condition) or in front of both participants (*Equal Liking* condition; see Figure 4 A, C). It then turned its front part up twice (simulating nodding) in the direction of one or both participants.

To further enhance the robot's demonstration of peer liking, we also manipulated its interpersonal distance from the participants. Prior work from psychology indicates that physical distance is a robust social cue representing closeness and social distance [93]–[95]. Smaller physical distances are associated with greater emotional closeness, greater empathy, and greater willingness to take part in an interaction [96]–[101]. Similar effects have also been indicated in the context of HRI, where the physical distance between a human and a robot was interpreted as representing the relationship between them [102]. We therefore manipulated the robot's interpersonal distance from the participants under both conditions. In the *Unequal Liking* condition, the robot finished the opening encounter by moving closer to the "Liked" participant and standing next to him\her, on the far side with respect to the other participant (see Figure 4 D). In the *Equal Liking* condition, the robot finished the opening encounter by moving closer to the area between the participants and standing between them at an equal distance from each participant (see Figure 4 B).

We additionally designed gestures for the search task: *Understanding*, to indicate that the robot understood the task given to it by the participants during the search activity; *Scanning*, to indicate that the robot was scanning the symbols on the cube; and *Finding*, to indicate that the robot has found a symbol. They were performed as follows:

Understanding: When the participants addressed the robot, it entered a position simulating a dog sitting and moved its head gently right and left as if mapping the information presented to it. It then turned its front part up towards the participant twice (nodding).

Scanning: To scan, the robot leaned towards the cube (lowering its front part towards the cube) and performed right–left rotations of its head (indicating its focus and scanning of the cube).

Finding: To indicate finding a relevant symbol, the robot performed a scanning gesture followed by a ($\pm 360°$) turn next to the cube.

The gestures were designed via several iterations with an animator and an HRI expert, focusing on real dog gestures and indicating that the robot is performing the task. The understanding of these gestures was validated in a pilot study with 28 participants who were asked to explain the meaning of the gestures (presented in counterbalanced order). All participants easily understood the gestures.

B. Participants

Forty pairs of participants (with no previous acquaintance) participated in the study (80 participants, 44 women and 36 men; mean age = 24.78, SD = 4.25). All participants signed a consent form and received extra course credits or a 25 USD gift card. To control for possible gender influences (see [103], [104]), we tested single-gender pairs.

C. Experimental setting

The experiment was conducted in an open area outside one of the university buildings. The open area was in a quiet environment with bushes and building materials, which made it possible to hide the 12 cubes in a fixed location (see Figure 1). The participants began the experiment in a location that was marked as the beginning point (see Figure 1) and facing the open area. The task sheet with the code was placed on the ground behind the participants at an equal distance from both. The robotic dog was positioned out of sight and noticed by the participants only when it moved towards them.

D. Experimental design

This experiment used a 2×2 between-participant experimental design that included the following two factors: 1) *Robotic Condition* and 2) *Participant Coding*. The *Robotic Condition* was designed to compare the following two robotic behaviors: 1) *Unequal Liking*: The robot displayed its liking of and preference for one of the participants. The robot began its movement from one side of the field. It then proceeded toward one specific participant. The robot faced that participant and performed the opening encounter gesture (see Figure 4 C). The robot ended the opening encounter by positioning itself next to that participant (see Figure 4 D). 2) *Equal Liking*: The robot began its movement from one side of the field. It arrived at a location in front of and between the two participants and turned to face them. The robot then performed the opening encounter gesture towards both participants (see Figure 4 A). The robot ended the opening encounter by

Fig. 4. *Left - Equal Liking*: A - The robot performs an opening encounter in front of both participants; B - The robot standing between the participants; *Right - Unequal Liking*: C - The robot performs an opening encounter in front of a specific participant; D - The robot standing next to that participant.

positioning itself between the two participants (see Figure 4 B). The *Participant Coding* factor was designed to evaluate the different experiences of the participants within each pair. We randomly coded each participant in a pair as Participant A or Participant B. In the *Unequal Liking* condition, we consistently designed the robot to display liking only toward Participant A. In the *Equal Liking* condition, both Participants A and B were "Liked" by the robot. The participant pairs were randomly assigned to the different conditions. We verified that the conditions were balanced using two relevant pre-tests: Motivation to Lead (MTL, trait; [105]) and General Attitudes Toward Robots (GaToR; [106]).

E. Dependent measures

We assessed the impact of peer liking on emergent leadership using questionnaires and behavioral measurements.

1) Self-report measures: To measure whether participants perceived themselves as leaders, we used the following two questionnaires:

Emerging leadership rating: We measured emergent leadership using a 6-point Likert scale, where team members evaluated their leadership in the task. The questionnaire items were adapted from Lanaj and Hollenbeck [107].

Responsibility perception: Participants were also asked to report to what extent they felt personally responsible for the team's performance on 10-point Likert scale [108] based on [109].

Robot perception: While not the focus of the study, we also evaluated the robot's perception using the Robotic Social Attributes Scale (RoSAS), which is a 9-point Likert scale (1: "low" and 9: "high") constructed of three sub-scales: warmth, competence, and discomfort [110].

2) Behavioral measures: To measure participants' leadership, we also used two behavioral measures: 1) which participant picked up the task sheet to manage the task and 2) the amount of time each participant managed the task by holding and filling in the task sheet. Two independent coders reviewed the videos and verified that their coding was consistent.

3) Qualitative measure: Semi-structured interview: A semi-structured interview was conducted to better understand the participants' thoughts and attitudes [111]. The interview was designed to understand participants' overall experience, thoughts about the task, the other participant, and the robot (e.g., "Describe your experience" and "What did you think of the other person who performed the task with you?").

F. Procedure

A few days before the experiment, participants received an email with questionnaires assessing the MTL [105], GaToR [106], and demographics. Upon arriving at the lab, participants were led to the open area outside the building. The researcher asked the two participants to stand in front of the open area in two marked spots and told them that they were about to perform a task as a team and that a robotic dog would join their team shortly. The researcher then instructed them to wait a few seconds until the experiment began and moved out of sight to allow them to pay full attention to the approaching robotic dog. The robotic dog then joined the participants and performed the opening encounter behavior, demonstrating peer liking according to the relevant condition. The researcher then returned and explained the task, asked participants to pick up the task sheet placed behind them, and emphasized that the team's task was to decipher the code together in the most efficient way. Next, the researcher set the participants' expectations of the robotic dog's capabilities, explaining that it could search for symbols and signal with a gesture when it found a relevant symbol. The researcher asked the participants to plan a strategy for the search task and explain it to the robotic dog. After the participants explained to the robot what it should do, the robot performed the understanding gesture and turned toward the open space, signaling that it was ready to begin. The participants then performed the search task, which ended after they had deciphered the code. Immediately after the participants finished the task, they filled out the questionnaires and participated in a short interview (separately and in different locations). At the end of the experiment, the researcher debriefed the participants and verified that they left with an overall positive experience.

IV. Analysis

To verify the lack of early differences between groups, we conducted Bayesian analyses on the results of the pre-tests. To analyze the robot's impact on emergent leadership, we conducted two-way ANOVA of its influence on participants' reports of their sense of leadership, sense of responsibility, and on the amount of time they managed the task by holding and filling in the task sheet. The impacts of two independent factors were evaulated: 1) *Robotic Condition – Equal Liking* vs. *Unequal Liking* (peer liking) and 2) *Participant Coding* – Participant A or Participant B, representing the different experience within each pair (see Section III-D). We also conducted a chi-square analysis to test the dependency between the *Robotic Condition* and the participant who initially picked up the task sheet to manage the task. The interviews were analyzed using thematic coding [111], which included transcriptions and review of all interviews. We then identified initial themes in a process that involved three researchers who independently identified repeating patterns, discussed inconsistencies, and reached mutually agreed themes. The researchers then independently analyzed a subset of the interviews to verify inter-rater reliability (Kappa=88%) and analyzed the remaining data.

V. Results

The Bayesian analysis indicated no early differences between groups (GaTor: $BF_{10} = 0.29$; MLT: $BF_{10} = 0.22$). The quantitative and qualitative main analyses indicated an impact of the robot influence on emergent leadership.

A. Self-reported measures

1) Emergent leadership rating: The two-way ANOVA assessing participants' perception of their leadership in the team revealed a significant interaction between the *Robotic Condition* and the *Participant Coding*, $F_{(1,76)} = 4.76$, p = 0.032. Post-hoc analyses using planned contrast indicated that under the *Equal Liking* condition, Participant A and Participant B reported similar perceived leadership ($p_{contrast}$ = 0.46). By contrast, under the *Unequal Liking* condition, Participant A (who was "Liked" by the robot) reported higher leadership ratings ($p_{contrast}$=0.019; see Figure 5, Left). The interaction indicated that when the robot showed a clear liking toward one of the participants, that participant had a greater sense of leadership than the other participant in the team. The main effects were not significant.

2) Responsibility during the search task: The two-way ANOVA analysis of participants' responsibility ratings revealed a significant interaction between the *Robotic Condition* and the *Participant Coding*, $F_{(1,76)} = 4.04$, p = 0.048. Post-hoc analyses using planned contrast indicated that under the *Equal Liking* condition, Participant A and Participant B reported similar responsibility ratings ($p_{contrast}$ = 0.76), while under the *Unequal Liking* condition, Participant A reported taking more responsibility than Participant B ($p_{contrast}$=0.002; see Figure 5, Middle). This interaction suggests that when the robot exhibited a preference for one of the participants, that participant reported taking more responsibility in the search task. The *Participant Coding* main effect was also significant, $F_{(1,76)} = 6.1$, p = 0.015. The *Robotic Condition* main effect was not significant.

B. Behavioral measurements

1) Picking up the task sheet: The chi-square analysis revealed a significant dependency between the *Robotic Condition* and *Participant Coding*, ${\chi^2}_{(1)} = 3.75, p = 0.05$. Under the *Equal Liking* condition, there were hardly any differences, and either Participant A or B would pick up the task sheet. Under the *Unequal Liking* condition, the observation revealed that in most cases, Participant A picked up the task sheet at the beginning of the task (see Table I).

TABLE I
Distribution of which participant picked up the task sheet.

Robotic condition	**Participant picking up the task sheet**		**Total**
	Participant A	**Participant B**	
Unequal Liking	15	5	20
Equal Liking	9	11	20
Total	24	16	40

2) Time spent managing the task: The two-way ANOVA analysis for the amount of time participants managed the task by holding and filling in the task sheet revealed a significant interaction between the *Robotic Condition* and *Participant Coding*, $F_{(1,76)} = 5.76$, p = 0.019. Post-hoc analyses using planned contrast revealed that under the *Equal Liking* condition, there was no significant difference between the time each participant managed the task ($p_{contrast}$ = 0.4), whereas under the *Unequal Liking* condition, Participant A managed the task longer than Participant B ($p_{contrast}$=0.015; see Figure 5, Right). This interaction indicates that when the robot showed a clear liking towards one of the participants, that participant tended to take a more dominant role in managing the task.

C. Robot perception

The two-way ANOVA analysis of the RoSAS did not reveal any significant effects in any of the sub-scales.

D. Qualitative: Semi-structured interviews

In total, 593 quotes were coded into three main themes: leadership and responsibility, dynamics with other team members, and the influence of the robot on team members.

1) Theme 1: Leadership and Responsibility: Leadership of the tast was discussed by 72/80 participants. Some participants perceived themselves as leaders, others perceived the other participant as the leader, and some described how leadership was shared with the other participant.

Under the *Unequal Liking* condition, 39/40 participants discussed leadership. However, the participants within each pair demonstrated different attitudes. Among those who were "Liked" by the robot, most participants perceived themselves as the team's leader (13/20): *"I led. I said what we should do and we did it. She didn't offer anything else."* (P. 48, F). A few participants also reported that they shared leadership with the other participant (6/20): *"We shared the responsibility, communicated equally with the robot, and found symbols."* (P. 22, M). Only one participant who was "Liked" by the robot described the other participant as the leader (1/20): *"I was the one who started the task but at some point he took over."* (P. 1, M). The participants who were not "Liked" by the robot, demonstrated an opposite pattern. Only one participant

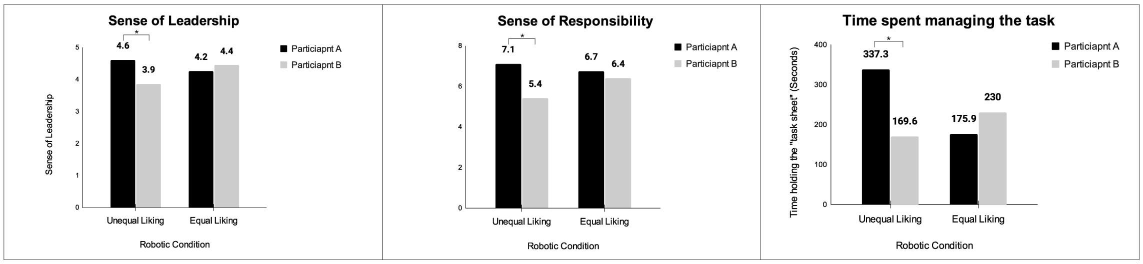

Fig. 5. *Robotic Condition* and *Participant Coding* impact on leadership (*Left*); responsibility (*Middle*); and time managing the task by holding the task sheet (*Right*).

reported leading the team (1/20): *"I felt that I managed the task."* (P. 78, M). A few participants reported that they shared leadership with the other participant (7/20): *"I threw out an idea and he threw out an idea. So no one was the clear leader."* (P. 21, M). Most participants who were not "Liked" by the robot reported that the other participant led the team (11/20): *"She really stepped into a leadership role. She did it nicely, not giving me direct instructions."* (P. 33, F).

Under the *Equal Liking* condition (no difference in the robot's liking), 36/40 participants discussed leadership. More than half (23/40) mentioned that they shared leadership with the other participant: *"I felt that we were together in it, that we are on the same page, synchronized."* (P. 11, F). In addition, 12/40 participants reported that they were the team leaders: *"I was the leader. I explained the strategy, I took control, and I wrote down the code."* (P. 64, F). Only 1/40 participants perceived the other as the team's leader: *"She was like the leader. She wrote the code in the sheet."* (P. 16, F).

2) Theme 2: Dynamics with other team members: Positive and negative team dynamics were discussed by 79/80 participants.

Under the *Unequal Liking* condition, 40/40 discussed team dynamics. However, participants within the pairs demonstrated different attitudes. Most participants who were "Liked" by the robot reported positive dynamics (16/20). They described teamwork and consideration of the other participant: *"I planned a strategy and asked if she was okay with it. We worked well together"* (P. 7, F). Only 4/20 reported negative dynamics: *"She didn't understand; it was a mess."* (P. 19, F). Amongst the participants who were "Liked" by the robot, half (10/20) reported positive dynamics, stating that they contributed to the team effort: *"We worked in collaboration and searched for the symbols together."* (P. 14, F). The other half of the participants who were "Liked" by the robot reported negative team dynamics (10/20), explaining the interaction was not balanced and minimal: *"I felt she was more connected to the robot and wanted to start right away without planning."* (P. 20, F).

Under the *Equal Liking* condition (no difference in the robot's liking) 39/40 discussed team dynamics. Almost all participants reported positive dynamics (38/39): *"I had fun with her, I feel that we were in a flow and had great teamwork."* (P. 43, F). Only one participant in this condition described negative team dynamics (1/39): *"In the end we needed to divide resources. So he went with the robot and I went by myself."* (P. 6, M).

3) Theme 3: The influence of the robot on team members: The robot's influence was explicitly discussed by 27/80 participants.

Under the *Unequal Liking* condition, 14/40 participants discussed the robot's influence. However, the participants within the pairs shared different perception of the robot's impact. Participants who were "Liked" by the robot described only positive influences (10/20): *"He sat next to me, like a wing man. It's like in the* Borat *movie, as if he says, 'You are the King of the Castle.'"* (P. 51, M). In contrast, participants who were not "Liked" by the robot either did not mention any robotic influence or described a negative impact (4/20): *"He looked at us and stood next to the other person. Honestly, it pissed me off. I wanted him to stand between us."* (P. 10, M).

Under the *Equal Liking* condition (no difference in the robot's liking), 12/40 participants described positive influences. They explained that the robot enhanced the team's ability to perform the task: *"He stood between us, and it made me feel that he was committed to us and that we have another great team member that would help us perform the task."* (P. 36, F). Only one participant from this condition described a negative influence (1/40): *"It made me feel weird, uncomfortable."* (P 54. F).

VI. Discussion

In this study, we demonstrated the potential of leveraging robots to encourage emergent leadership in teams. By integrating a peer robot designed to explicitly "Like" a specific team member, we showed how the dynamics between people in a team can be shaped and how informal leadership can develop. Our findings further indicate that peer liking displayed at the very beginning of the interaction is sufficient for setting the leadership dynamics in the rest of the interaction. A simple positive encounter directed towards a specific participant and a short period of closer interpersonal distance encouraged participants to take responsibility and lead the team. These effects were observed even though participants were not asked to choose a leader and leadership was not required to perform the task. Being "Liked" by the robot led to higher ratings of self-perception of leadership and a sense of responsibility. Furthermore, the "Liked" team member also showed greater tendencies to pick up the task sheet and spent more time using it to manage the task. Because the task sheet was the main tool for controlling the task, this led to greater dominance within the team [112]–[115].

Interestingly, when the robot did not show a preference toward a specific participant (the *Equal Liking* condition), participants frequently managed the task together. This suggests that informal leadership may not emerge without an external intervention, and its associated advantages would be missed. Simply adding a robot to a team is not likely to facilitate leadership unless the robot is designed according to the social requirements that support emergent leadership (i.e., peer liking). By contrast, if shared leadership is desired, our findings imply that it can be facilitated by introducing to the team a robot that displays mutual liking. While not directly tested in this study, our qualitative findings strongly suggest that under the *Equal Liking* condition, participants perceived the interaction as high-quality collaborative teamwork.

Our findings also suggest that people's tendency to interpret interactions with robots as social experiences (see [116]) extends to the phenomenon of peer liking and its implications on emergent leadership. Similar to the impact of being liked by human team members, a robot's liking by simple robotic non-verbal behavior was sufficient for supporting the emergence of informal leadership. Despite the robot's mechanical nature, dog-like appearance, and its inability to engage in a verbal interaction, its simple social cues led that participant to experience a clear sense of peer liking *(e.g., "He was committed to me." or "It chose me.")*. The robot's peer liking toward one team member resulted in an effect on leadership that is typically observed in the presence of human peer liking. This effect implies that similar to interactions with humans [49], interactions with a robotic team member can grant the social power required to empower a specific team member and encourage the development of leadership. Our findings therefore suggest that robots present a strong opportunity for supporting informal leadership while preserving its special advantages.

Our findings further extend the scope of human social dynamics that can be shaped by robots [1], [117]. Specifically in the context of leadership, previous studies indicated robots' ability to lead human teams and the possibility of alternating between human and robotic leadership [29], [30], [78]–[85]. We extend this literature by demonstrating that robots can shape and encourage human leadership in teams that do not have a formal leader. Most participants under the *Unequal Liking* condition, both those who were and were not "Liked" by the robot, exhibited the well-known advantages of informal leadership and reported positive team dynamics even if they were not the team leaders (*"She really cared about my opinion. We had great teamwork."*). At the same time, our findings also indicated that the robot's peer liking could lead to some negative effects. The clear preference of one team member led in some cases to a sense of social imbalance. A few of the participants who were not "Liked" by the robot were not satisfied by the team dynamics (*"It was kind of divide and conquer instead of working together."*). This effect should be further studied to minimize any negative effects related to the robot's preference of one team member over the other.

An additional implication of our results concerns the importance of opening encounters with robots. While psychology studies have already indicated the long-term impact of opening encounters on the interaction that follows [62], [63], [118], in HRI, the impact of opening encounters was tested by evaluating participants' tendencies to help the robot shortly after the opening encounter [54], [55], [59]. Our findings indicated that similarly to human interactions, opening encounters with robots can have a long-term effect that influences the entire interaction. The "Liked" participant in the *Unequal Liking* condition led the interaction throughout the experiment and managed it by holding the task sheet. The leadership of the task was not often alternated between the participants, and the impact of the robot's behavior in the opening encounter lasted until the task was completed. We therefore further demonstrated the importance of carefully considering the impact of opening encounters with robots and their powerful, long-lasting impact on the interaction that follows.

Taken together, our findings suggest that integrating a robot into a team of humans can be leveraged to shape team processes that are less likely to be shaped by humans. For example, consider the case of Agile teams, in which the different skills of team members should be integrated into collaborative teamwork [**?**] so that every member's input is valued. A balance in teams typically leads to an unstructured organization [119]. Despite the common self-organisating nature of such teams, they can highly benefit from leadership that maximizes performance by organizing teamwork while respecting and empowering all team members. Such teams are known to thrive when leadership emerges from within the team [120], [121]. Our work suggests that by integrating a robot into the team and carefully designing the robot's social behavior to display peer liking toward specific team members, team dynamics could be shaped in a way that would encourage emergent leadership. The robot can therefore encourage social processes that are not commonly influenced by individuals who are not part of the team. Our findings also suggest that in cases where the team should engage in shared leadership, it is important to verify that the robot displays a balanced peer liking towards all team members.

VII. Limitations

The study has several limitations. First, the specific robot used in the study was perceived as a complex advanced robot. It is possible that peer liking demonstrated by simpler robots would not have a similar impact on emergent leadership (although people tend to overestimate the capabilities of simple robots [122], [123]). Additional limitations concern the specific use of a search task. Future studies should test the impacts of a robot's peer liking in different tasks that have more meaningful consequences (risks or gains). It will also be important for future research to evaluate whether the robot has an impact on teams in which the team members are not strangers. Finally, the interviews might have been influenced by the interviewers' expectations and the "good subject effect" [124], [125].

VIII. Conclusion

Our work highlights the potential of leveraging robots to encourage emergent leadership in teams. We demonstrated how robotic peer liking toward a specific team member during an opening encounter can shape informal human leadership and achieve its associated advantages. In this way, robots present an opportunity to assist and intervene organically in the social dynamics that emerge from within a team while preserving the benefits that are commonly lost when presenting external human intervention.

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