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Enhancing Emotional Support: The Effect of a Robotic Object on Human–Human Support Quality

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Abstract

Emotional support in the context of psychological caregiving is an important aspect of human–human interaction that can significantly increase well-being. In this study, we tested if non-verbal gestures of a non-humanoid robot can increase emotional support in a human–human interaction. Sixty-four participants were invited in pairs to take turns in disclosing a personal problem and responding in a supportive manner. In the experimental condition, the robotic object performed emphatic gestures, modeled according to the behavior of a trained therapist. In the baseline condition, the robotic object performed up-and-down gestures, without directing attention towards the participants. Findings show that the robot's empathy-related gestures significantly improved the emotional support quality provided by one participant to another, as indicated by both subjective and objective measures. The non-humanoid robot was perceived as peripheral to the natural human–human interaction and influenced participants' behavior without interfering. We conclude that non-humanoid gestures of a robotic object can enhance the quality of emotional support in intimate human–human interaction.

Keywords Non-humanoid robots · Human–human robot interaction · Emotional support · Social support · Empathy · Caregiving

1 Introduction

Social robots are studied in several contexts including home, education, work, therapy, and health [1,50,52,111,122,125,126,133,136]. The social aspects integrated into a robot's behavior are believed to be a significant factor influencing the quality of the interaction between humans and robots [41] to the extent that they create human–machine communication (HMC) [58]. In such interactions robots become communicators, subjects with which people communicate [60]. They are perceived as social actors that take an active part in the interaction with humans [97]. It is therefore believed that communication is not a human-only process, and machines are not limited to mediating human–human interaction (HHI). Instead, robots can be communicative subjects within an interaction and can take different roles within the communication process [7,51,58–60,113]. These types of interactions have the potential to lead to meaning creation with wide implications for the humans taking part in the interaction [7,43,58,59].

A common practice in human–robot interaction (HRI) research is to design gestures that add social cues to the robot's non-verbal communication, which are believed to create a more natural interaction, enhance understanding of the information conveyed by the robot, increase engagement with the robot, increase the robot's likability, and its acceptance [41,73,93,112,125].

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Most studies concerning social robots evaluate interactions involving one human interacting with one robot [63,86,134]. In recent years a new subdomain is emerging within social robots research, focusing on social interactions that involve more than one human [50,73,94]. This field, sometimes called human–human–robot interaction (HHRI), typically involves a social interaction between two or more humans and a robot. Studies in this domain revealed that robots can have positive effects on human–human interactions and their outcomes [72,110,116,119,121,126]. These effects were shown with both humanoid robots that mimic human social cues (verbal cues, hand waving, smiling) [116], and with non-humanoid robots (also called robotic objects), that have limited communication modalities and leverage non-verbal gestures to communicate their social intent [4,72,110,121]. While non-humanoid robots cannot directly mimic human behavior, previous HMC and HRI studies indicated that even minimal movements of an abstract robotic object can lead to a consistent social experience [4,57,72]. Moreover, despite their limitations, non-humanoid robots are perceived as valid participants in a social interaction [65,71]. This is attributed to the well-known tendency of humans to anthropomorphize objects in the world around them [41,131]. Robotic objects are typically perceived through a social lens, to an extent that the social interpretation of their gestures is an automatic cognitive process that cannot be avoided [47].

HHRI studies explore a variety of social human–human contexts, including human–human interpersonal evaluation [110], conflict resolution [73,112], group performance [18,72], group trust [34,94,116], and conversational dynamics [66,94,121]. Robots' involvement in these contexts was shown to influence participants' emotion regulation during a discussion [66], participants' extent of active participation in the interaction [50,94,121], participants' evaluation of each other [72,110,119], and participants' awareness of tension between group members [73,112]. These HHRI studies along with studies from the HMC area indicate that both humanoid and non-humanoid robots can influence the interaction between humans, either directly or indirectly [58]. In this work, we suggest to explore the possibility that a non-humanoid robot will positively influence a more intimate human–human interaction that requires human empathy, sensitivity, and attention, such as provision of emotional support to a friend who is disclosing a personal problem.

Emotional support in the context of psychological caregiving is defined as providing empathy, comfort, understanding, acceptance, and reassurance that increase a person's feeling of being loved, cared for, and protected by others during times of stress [38]. The person seeking support is commonly referred to as the "care-seeker" while the person providing the support is referred to as the "care-giver" [31]. Hence, caregiving in this context differs from the popular caregiving interpretation of providing care for populations with dependency needs [13].

Emotional support is considered one of the most significant human–human interactions, with short-term and long-term positive influences on humans' emotional state and well-being [8,14,28]. Individuals experiencing stressful events typically reach out to significant others for protection, assistance, and emotional support [15]. Such interactions involve care-seeking efforts by one person and care-giving responses by another person [31]. Care-seeking behaviors are observed in a wide range of situations such as children seeking emotional support from their parents in times of need, adults disclosing personal concerns to a close friend, couples dealing with everyday stressful events and more [24,31,88]. When emotional support is not properly provided (when needed), care-seekers are believed to experience negative effects that drastically influence their emotional state and general well-being [22,80,88].

The provision of high-quality emotional support behaviors includes care-giver's active listening and understanding, validating, and accepting the care-seeker's needs and behaviors while avoiding negative behaviors such as dismissing the problem or blaming the care-seeker [31]. When properly provided, high-quality emotional support has positive influences both in the short and long term. In the short-term, provision of high-quality emotional support is associated with decreasing negative emotions related to helplessness, anxiety, depression, and rejection. In addition, high-quality emotional support was shown to increase positive emotions, including hope, love, gratitude, forgiveness, relief, and security [8,33,75,124]. In the long-term, the provision of high-quality emotional support has been found to contribute to mental health, well-being, personal growth, relationship satisfaction, and even physical health [22,39,55,56,81]. Even minimal acts of high-quality emotional support have been associated with such long-term effects [24,28,39].

Providing high-quality emotional support is not a trivial task [69]. The care-giver is required to identify the care-seeker's needs and in turn adjust his/her own responses accordingly [8,31,38]. Emotional support typically involves three empathy-related behaviors: verbal empathy, non-verbal immediacy, and interpersonal coordination. Verbal empathy (also known as "verbal person centeredness") is a verbal expression of empathy and validation of the care-seeker's feelings (for example, "I hear what you say, it is very frustrating") [21]. Non-verbal immediacy includes supportive non-verbal behaviors such as smiling, eye-gaze, body orientation, and head-nods. These non-verbal gestures are believed to play an important role in the emotional support process [130,132] by explicitly reflecting empathy, interpersonal warmth, and psychological closeness [30,42]. Furthermore, care-seekers often report that the mere presence of the care-giver and the feeling that he/she is "there for them"

Fig. 1 The robot used in the study (previously published, used with permission; Hoffman et al. [66]) is a simple 2 Degree-of-Freedom non-humanoid robotic object, capable of performing several gestures, including Gaze, Lean, and Nod

Fig. 2 A human–human emotional support interaction, with a robotic object performing empathy-related non-verbal gestures

(communicated through non-verbal gestures) is more important than specific advice or verbal empathy remarks [61,127]. Interpersonal coordination is defined as synchronization and mimicry of the care-seeker's behavior. For example, the care-giver's adjustment of body position to be compatible with the care-seeker's body (e.g. changing legs position by the care-seeker followed by a similar legs position change by the care-giver) is believed to implicitly reflect empathy and understanding [10,25,107].

Humans' ability to provide such high-quality emotional support depends on several factors, including empathy skills, emotional resources, and a sense of attachment security [31,48]. Even though some of these factors are relatively stable across life, previous studies indicate that empathy-related behavior can be improved by modeling emotional support behavior, providing feedback on appropriate behavior, and training relevant communication skills [67,74]. In addition, the subjective perception of the emotional support experience has been found to have a greater impact on the care-seeker's emotional state than the actual objective support provided by the care-giver [29,76,129]. These findings suggest that it is possible to positively influence an emotional support interaction between two people in two ways: (1) by providing the care-giver with a model for behaviors related to high-quality emotional support; and (2) by increasing the care-seeker's subjective sense of being cared for. Based on these findings we suggest to test if a non-humanoid robot can enhance a human–human emotional support interaction. The robot is designed to (1) model empathy-related behavior, in an effort to influence the care-giver's behavior, and (2) to provide empathy towards the care-seeker, in an effort to enhance the subjective perception of emotional support (Fig. 1).

In this work, we present a systematic evaluation of a robot's influence on the quality of an emotional support interaction between two friends (see Fig. 2). We test if the robot's empathy-related behaviors (directed towards the care-seeker) can indirectly enhance the emotional support quality in the interaction. Based on previous studies indicating that even minimal acts of caring are sufficient for creating an impact [24,28,39], we hypothesize that the minimal gestures of a robotic object will enhance the quality of the emotional support experience.

The specific choice of a non-humanoid robot was designated for preserving the human–human nature of the interaction and for minimizing the interruptions of the robot's movement to the communication. We, therefore, decided to not use a humanoid robot, but rather a small non-humanoid robotic object, reminiscent of a lamp, that was deliberately designed to be peripheral to human–human interaction [66,135] (see Fig. 1). Another advantage of using a non-humanoid robot is related to minimizing participants' unrealistic expectations from the robot's behavior, as sometimes reported in HRI studies involving humanoid robots [41,64,91,103]. It is however left to be tested if a simple robotic object that cannot mimic human behavior, with limited movement capabilities and a limited set of gestures, can positively impact an intimate human–human interaction such as emotional support.

We present a study based on the well-known psychological caregiving experimental paradigm, designed by Collins and Feeney [31], in which two participants take turns in disclosing a personal concern. Our study involves two conditions, an experimental condition in which the robot performs empathy-related gestures towards the care-seeker participant, and a baseline condition where the robot performs a repetitive gentle movement without attending any of the participants. We tested the effect of the robot's behavior on the emotional support quality using both subjective measures (care-seeker's and care-giver's self-reports of the quality of the interaction) and objective measures (interpersonal coordination, care-giver's verbal empathy, and non-verbal immediacy behaviors).

2 Related Work

Prior work includes two main categories: (a) Technologies including chatbots, virtual agents, and robots designed to provide emotional support and empathy; (b) Robots designed to influence human–human interaction.

2.1 Technologies Designed to Provide Emotional Support or Empathy

Previous studies that explored technologies relevant for emotional support typically focused on providing empathy and involved one human interacting with the technology. These studies indicate that empathic cues can provide comfort and improve the interaction between the human and the technology [105,111,125]. One of the earliest technologies designed to provide empathy is an internet-based software called "Eliza" [128]. The software, developed in 1966, simulates therapeutic interventions and takes the role of a therapist asking people to describe their feelings. The software is designed to generate text-based sentences with a supportive and friendly tone motivating users to perform self-observation on their emotions. Later studies with "Eliza" indicate that users attribute human-like feelings to the software [95] and disclose emotions as if it was a therapist [36]. Similar findings were reported in recent studies evaluating AI chat agents and AI software tools designed to provide support and therapy. These tools typically provide sensitive medical advice or self-help instructions [49,83,87,92] and utilize empathy-related techniques, such as sympathy, cognitive empathy, and affective empathy, to increase acceptance and engagement [83,87,92]. VR and digital avatar agents were also designed to provide empathic experiences [90,102,106]. Agents' empathy is typically implemented by mirroring the participant's non-verbal behavior in an effort to communicate an emotional state [17,82]. Empathy based processes were also applied via supportive verbal responses relevant for the conversation [90,99,106] or even simply asking questions that indicate interest in the participant's state [78,90]. Results from studies involving virtual agents indicate that in some cases users feel more comfortable disclosing personal information to virtual agents in comparison to humans [85,117]. This preference is attributed to increased anonymity, objectivity, and security associated with the agent [117] along with a feeling of not being observed or judged [85,117]. As a result, virtual agents are perceived as supportive and "safe" interaction partners [117]. In addition, adding empathy-related features to virtual agents have been found to lead to more positive interactions [82,99] and to increase virtual agents' likeability, trust, and caring [17].

Robots were also studied as technologies for providing empathy. Empathy robots typically take a humanoid or zoomorphic form and involve an interaction between one robot and one human. Robots' empathy-related behaviors as verbal communication [35,79,98,105,125] and non-verbal cues [62,109,120] were indicated as factors influencing participants' perception and acceptance of the robot. Robots that leverage non-verbal cues to provide empathy commonly utilize interpersonal coordination to increase empathy by mimicking participants' behavior. Interpersonal coordination typically includes a robot mirroring the participant's facial expressions [62,109] and head orientation [108,109]. These interactions were perceived as involving high levels of emotional support [105,108,120] and increased the robot's acceptance [26,108,109].

Similar to the interaction with one human, studies with robots in a human–human interaction context showed that verbal empathy and non-verbal mimicry are associated with a positive evaluation of the robot. For example, the iCat zoomorphic robot was integrated as a social companion in an interaction between two chess players, providing verbal empathy towards one player and neutral behavior towards the other. The iCat's empathic behavior led participants to rate the robot as significantly higher in companionship capability, reliability, and ability to support the player's positive self-image [79]. Another HHRI study that tested participants' perception of a robotic object during a conversation between couples, indicated that the empathic behavior performed by the non-humanoid robot led to higher ratings of the robot as being "more human" and "more similar" to the participants [66].

Taken together these studies indicate that robots are able to model empathy-related behavior and to positively influence participants' perception and acceptance of the robot. However, robots' influence on humans' perception of each other (not the robot), and their capability to provide emotional support to each other, is yet to be tested.

2.2 Robots' Influence on Human–Human Interaction

A small set of pioneering studies within the HRI community have evaluated the effect of robots' behavior on human–human interaction (instead of the way humans perceive the robot). Humanoid and zoomorphic robots, that mimic human behavior (both verbal and non-verbal behavior), have been found to influence humans' participation in a conversation [94], to increase trust in a group context [116], to improve performance on tasks requiring collaboration [2,72], and to assist in conflict resolution [112].

Non-humanoid robots were also shown to influence human–human interactions, despite their limited communication modalities and inability to directly mimic human behavior. For example, a Roomba vacuum-cleaner robot was shown to alter the dynamics of household members (in comparison to a Flair traditional handheld stick vacuum). The Roomba led to increased engagement of more family members in the house cleaning process [50]. Another example of a robotic object changing group dynamics is the Micbot, a robotic object resembling a microphone, that increased engagement and participation of members in a conversation by shifting its attention towards passive group members using non-verbal gestures [121]. Robotic objects have been also found to negatively influence HHI. For example, a robotic arm that collaborated with two humans in building a wooden tower negatively influenced their interpersonal evaluation by employing an imbalanced responsive behavior. The participants' task was to build the highest possible tower from blocks given to them by the robot. The robot handed out blocks to the participants either equally or unequally. The blocks distribution by the robot affected participants' performance (tower's height) and their perception of one another. Participants in the unequal distribution condition reported a significantly lower evaluation of their partner [72].

Specifically, in the context of two humans interacting with one another, Riefinski et al. [110] tested the influence of a robotic object on interpersonal evaluation in a human–human conversation. The robotic object, reminiscent of a lamp, was designed to be peripheral to the conversation and to promote calm, non-aggressive human–human conversation [66]. The robot's non-verbal gestures significantly improved participants' interpersonal evaluation and led to higher ratings of the human conversation-partner. Participants' direct perception of each other and the quality of the interaction between them were significantly improved when the robotic object was attentive to the conversation [110]. This effect was observed despite the robot's non-humanoid form and limited communication modalities. Moreover, participants accepted the robotic object as a side-participant in the conversation and did not expect the robot to take an active or equal part in the conversation.

In this work we evaluate if a robot performing empathy-related non-verbal behaviors can positively influence an emotional support interaction between two human participants, and improve the quality of the support provided in the interaction. We used the same robotic object used by Hoffman et al. (2015) and Rifinski et al. (2020) (see Fig. 1), a low DoF non-humanoid robot designed to be an empathy object that peripherally supplements and enhances HHI, without distracting it, or replacing one of the humans (see also Zuckerman et al. 2015; [135]). This robot was previously shown to enhance human–human conversation without altering the nature of the human–human interaction and without being perceived as intrusive [110]. We evaluated the influence of the robot's gestures (designed to provide empathy through non-verbal immediacy cues) on the quality of the human–human emotional support interaction.

Fig. 3 A pilot study with a therapist mediating an emotional support interaction between two participants. The robot's gestures were designed based on the therapist's movement during the interaction

3 Robot's Gestures Design and Implementation

3.1 Design

To properly define the empathy-related gestures that the robot should perform during the human–human emotional support interaction, we conducted a gesture elicitation pilot study with an experienced therapist. Gesture elicitation is one of the common methods used when designing social gestures for non-humanoid robots that cannot directly mimic human behavior (e.g. Zuckerman et al. [137]). Additional methods include 3D-animation gesture studies, Skeleton Prototype studies, Video prototyping, and Wizard-of-Oz (WoZ) gesture studies (for a review see Hoffman and Ju [64,65]). We chose to focus specifically on the gesture elicitation method since our aim was to identify non-verbal behavior relevant for mediating emotional support interactions, that are intimate and sensitive. Based on previous studies that indicated the possibility of modeling non-humanoid robotic gestures by observing human non-verbal behavior [137], we observed the natural non-verbal behavior of an experienced therapist that was asked to mediate and enhance an emotional support interaction between two participants (see Fig. 3). This choice is supported by previous studies that used human communication as a model for designing communication with technology [58,96], indicating that human communication may be applicable to interaction with robots [44,45].

The therapist was an experienced clinical psychologist with specific expertise in couple therapy and in promoting and encouraging emotional support interactions. The gesture elicitation pilot was conducted in the same context as the study and included three sessions, each with a different pair of participants. In each session, one of the participants (randomly chosen) was invited to disclose a personal problem, and the other was asked to respond in a supportive manner. The session lasted 5 min based on the therapist's evaluation that it is sufficient for sharing a meaningful personal problem. The therapist was asked to mediate the interaction in a manner that will maximize the emotional support provided by the care-giver while minimizing the use of verbal responses unless she feels it is necessary for maintaining a natural interaction. The sessions were videotaped and analyzed together with the therapist, observing her behavior that mostly involved non-verbal immediacy cues.

The analysis focused specifically on insights that could be useful for the robot's gesture design, including: (1) The therapist used non-verbal immediacy cues, such as gaze towards participants, lean towards participants while slightly moving, nodding to communicate empathy, and occasionally smiling; (2) The therapist's direction of movement revealed an unexpected insight. The therapist's body orientation was constantly directed towards the care-seeker, even when gazing at the care-giver. From the beginning of the interaction, the therapist shifted her body orientation towards the care-seeker and did not change it until the end of the session.

Based on these insights we defined two variations of a "gaze-lean-nod" gesture sequence, leveraging previous work with this specific robot, indicating that gestures towards participants were perceived as "lean" and "gaze" [66,110,135]. The sequences, that included a gaze, lean-in, and slight nodding, were similar to one another, with a slight change in the lean-in and nod angle. The two gesture sequences were termed "gaze-lean-nod 1" and "gaze-lean-nod 2". We additionally designed a "dominant turn" gesture, aiming to direct full attention towards one of the participants and not towards the other. In addition, we designed a gentle "up-and-down" sequence as if the robot is "breathing slowly" (without any lean or gaze movements), to be used in the baseline condition (see Table 1).

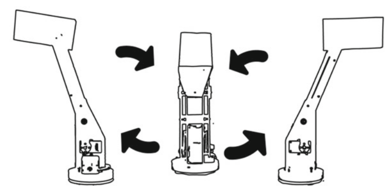
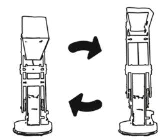
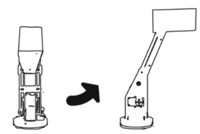
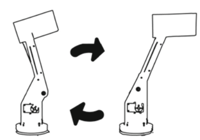
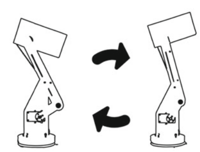
To define a gesture activation protocol for a Wizard-of-Oz human controller, we performed another pilot study with two participants, and this time invited the therapist to join the "wizard" (the human controlling the robot remotely) in the control room. The therapist was introduced to the available gestures and was asked to instruct the wizard which gesture to perform during the interaction. Immediately from the beginning of the session, the therapist used the "dominant turn" to direct the robot's attention towards the care-seeker, and then shifted between the different "gaze-lean-nod" sequences towards the care-seeker throughout the session. The therapist decided not to shift away from the care-seeker during the entire interaction. Following on the therapist's instructions to the wizard, we approximated shifts between the two lean variations to be 30 or 60 s. Moreover, since the robot's design couples direction of gaze with direction of lean, based on the therapist's decision, we decided to keep the robot directed towards the care-seeker throughout the interaction, even when the care-giver was speaking. When reviewing the literature, we learned that emotional support studies validate the therapist's decision, suggesting that care-seekers are attuned to their partner's attentiveness and that even minor attention shifts can negatively influence the emotional support interaction [32,130].

The sessions with the therapist led to defining two final gesture activation protocols for the study's conditions: experimental condition and baseline condition. The experimental condition WoZ protocol included: A "hello" sequence that involved a turn towards each of the participants one after the other followed by a "gaze-lean" gesture towards each of them; then a "dominant turn" gesture towards the care-seeker that directed the robot's attention to the care-seeker only, followed by a 5 min sequence of shifting between "gaze-lean-nod 1" and "gaze-lean-nod 2" until the session ended. The baseline condition WoZ protocol included: A "hello" sequence similar to the one in the experimental condition; then when the conversation started, a gentle "up-and-down" sequence for the whole 5 min of the session, without directing attention to either of the participants (robotic object facing the space between the participants). In both conditions, at the end of the session when the conversation ended, the robot performed the gentle "up-and-down" sequence during the questionnaires and debriefing parts of the experiment. As participants switched roles after the first 5 min session, this protocol was activated again for the second session.

3.2 Implementation

The non-humanoid robot used in this study includes a WoZ module and a behavior module. The WoZ module allows a human controller to operate the robotic object's gestures or sequence of gestures using a control app from a control room. For this work, we created new gesture sequences that matched our study goal, as described in the section above. The gesture sequences were implemented as a fixed timer-based movement, designed based on the guidelines defined in the pilot study with the experienced therapist. Unlike reactive robot architectures, such as the Sense-Act-Modulated-by Interactions (SAMI) architecture [23] that leverage real-time sensing of the world to trigger corresponding actions, we chose a simple timer-based architecture to verify there are no differences in the robot's reaction time and movement

Table 1 Gesture activation protocols for both baseline (baseline-robot) and experimental (empathic-robot) conditions. Gestures were triggered according to the protocol during the 5 min session, and again once the care-seeker and care-giver roles have shifted

Gesture or sequence	When used	Figure
"Hello" sequence	Performed once at the beginning of both baseline and experimental conditions	
Gentle "up-and-down" sequence	Performed all along the Baseline condition. Seems like a "slow breathing" movement. Also activated during the questionnaires and debriefing part in both conditions	
"Dominant turn" gesture	Used at the beginning of the Experimental condition, following the initial "hello" sequence, to turn towards the care-seeker. Also used at the end of the condition, to turn back to the middle	
"Gaze-lean-nod 1" sequence	Used during the Experimental condition, for 60 s at a time. Starting after the "dominant turn" towards the care-seeker. Then shifting to the "gaze-lean-nod 2" sequence, and repeating when the "gaze-lean-nod 2" ends. After 3 sequences, a final "gaze-lean-nod 1" sequence is used for 30 s, then "dominant turn" back to the middle, and then the "up-and-down" sequence until the shifting of roles between participants	
"Gaze-lean-nod 2" sequence	Used during the Experimental condition, for 30 s at a time, following the "gaze-lean-nod 1" sequence, then performing the "gaze-lean-nod 2", and then shifting back to the "gaze-lean-nod 1" sequence	

behavior between participants. This simple architecture is not appropriate for real-world human–robot interaction with varying contexts but is appropriate for a controlled lab study that examines the influence of the robot's gestures on participants' behavior and reactions.

3.3 Ethical Considerations

The choice of the specific non-humanoid robot for this study follows the recommendation laid out in the Ethically Driven Robotics and Automation Systems Standard (IEEE P7007), and specifically the recommendation that a robot's design process should be carried out in a collaborative way through brainstorms and discussions with relevant stakeholders [101]. In our case, the robot is used only in academic studies for the sole purpose of understanding how the movement of a non-humanoid robot influences human behavior. The relevant stakeholders are psychologists, human–robot interaction researchers, engineers, animators, and members of the Institute Review Board (IRB) with expertise in ethics of technology. All the above-mentioned stakeholders were included in the process of choosing the robot for the study. The robot's specific movement design was decided together with an experienced therapist and a social psychologist who are experts in caregiving interactions. Our study design also follows the ethical recommendations laid out in the IEEE recommended practice for assessing the impact of autonomous and intelligent systems on human well-being [100]. Specifically, our study goal is aligned with the standard goal, to better understand how to create a positive outcome of A/IS on human well-being, in our case, increasing people's ability to provide emotional support (i.e., caregiving) to another person.

4 Method

We tested the robotic object's influence on an emotional support interaction from both the care-giver's and the care-seeker's perspectives, using subjective and objective measures. We evaluated if the non-verbal immediacy behaviors performed by the robot in the experimental condition increased the emotional support quality. We followed a well-known paradigm designed by Collins and Feeney [31] to assess psychological caregiving interactions between two participants. Although it is not the focus of this study, we additionally tested if the robot's behavior influenced participants' perception of the robot.

4.1 Participants

Sixty-four participants, all undergraduate students from the Communications, Psychology, and Computer Science schools participated in the study. We recruited participants with previous acquaintances in pairs of the same gender (males = 32, females = 32; mean age = 21.8 years, SD = 1.8 years). Participants reported their level of acquaintance from 1 (no former acquaintance) to 7 (strong friendship) (mean = 5.35 SD = 1.41). We avoided mixed gender pairs, following recommendations by Ashtonet and Fuehrer [6], suggesting to avoid inappropriate situations involving gender role, and Duck and Wright [40] suggesting that both men and women express themselves more openly to a same-gender friend. Previous acquaintance was a requirement based on previous psychological caregiving studies [31,37]. It resolves ethical concerns, related to the stress and embarrassment that may be involved in sharing a personal problem with a stranger. The requirement for previous acquaintance also enhances ecological validity, as emotional support interactions typically involve a close other and are less likely to occur with a complete stranger [118,130]. Students received extra course credit for their participation and signed a consent form. All procedures have been approved by the ethics committee of the university.

4.2 Experimental Design

Feeney and Collins [48] included two conditions, experimental empathic-robot condition and a baseline-robot condition. Participants were *randomly* assigned to one of the two conditions using a matching technique, that allows to balance potentially influential demographics across conditions, decreasing the possibility that the random assignment resulted in biased groups. In this study, we matched (balanced) groups for gender, level of acquaintance, and the reported stressfulness of the problem. Participants in both conditions were instructed to engage in an emotional support interaction, where the care-seeker discloses a personal concern, and the care-giver responds in a supportive manner. The robotic object was integrated as a side-participant in the conversation: a participant that is considered part of the conversation but is not being addressed [27,54]. In the empathic-robot condition, the robotic object performed empathy-related behaviors towards the care-seeker according to the activation protocol, without directing any gestures towards the care-giver. In the baseline condition, the robotic object performed the gentle "up-and-down" gestures towards the space between the participants according to the activation protocol, without attending any of them.

4.3 Dependent Measures

We used both subjective and objective quantitative measures. The subjective measures included questionnaires evaluating the subjective perceptions of the interaction for both the care-seeker and care-giver (evaluating both the care-seeker's perception of the care-giver's support and the care-giver's perception of her/his own support provision). The objective measures included behavior coding of interpersonal coordination, care-giver's non-verbal immediacy, and verbal empathy. The objective measures were analyzed by coding the emotional support interactions' videos. The video footage was coded by two independent raters, inter-rater reliability was calculated for every measure.

In addition, we evaluated the perceived stressfulness of the problem and participants' attachment orientation for validating the emotional support interaction and controlling for confounding effects. Although not the main focus of this study, we also evaluated participants' perception of the robot using the godspeed questionnaire and a short qualitative post-experimental interview.

4.3.1 Care-Seeker's Subjective Perceptions of the Interaction

This questionnaire evaluates the care-seeker's perception of the partner's emotional support quality. Care-seekers' subjective perception of the interaction was rated on a six-item scale developed by Collins and Feeney [31] (e.g. "Overall, how supportive was your partner during the interaction?"; "During the interaction, did you feel that your partner was responsive to your needs?"; "During the interaction, did your partner seem to understand the way you feel?"). Participants rated the extent to which they agree with each item on a 7-point scale, ranging from 1 (not at all) to 7 (very much). For each participant, we computed the total score (Cronbach's Alpha 0.86).

4.3.2 Care-Giver's Subjective Perceptions of the Interaction

The care-givers' subjective perception of the interaction was assessed with a similar six item scale measuring their own emotional support behavior during the interaction, also taken from Collins and Feeney [31] (e.g. "Overall, how supportive were you toward your partner?"; "During the interaction, did you feel that you were responsive to your partner's needs?"; "During the interaction, did you feel that you understood the way your partner felt about things?"). Participants rated the extent to which they agree with each item on a 7-point scale, ranging from 1 (not at all) to 7 (very much). For each participant, we computed the total score (Cronbach's Alpha 0.80).

4.3.3 Interpersonal Coordination

Interpersonal coordination assessment involved synchronization and mimicry events during the emotional support interaction [10,25,107]. Interpersonal coordination is defined as non-random behaviors, patterned behaviors, or synchronized behaviors between the participants [12]. Non-verbal correspondences to the care-seeker's non-verbal behavior typically include legs position, head orientation, hand gestures, and lean gestures [10,77]. The interpersonal coordination events were coded according to Bernieri and Rosenthal [12]. The change in non-verbal behavior was coded when it was similar in time (synchronization) or form (mimicry). An example for a mimicry-only event is when a change in the care-seeker's leg position is followed by a similar change in the care-giver's leg position. An example of a synchronization-only event is when a change in leg position is immediately followed by any non-verbal behavior, such as a hand gesture. All interpersonal coordination events were coded and summed as a single measure (Kappa = 80%).

4.3.4 Non-verbal Immediacy

Care-giver's non-verbal immediacy cues were identified based on the "non-immediacy" theory [3,70], including eye-gaze towards the care-seeker, smiling, body orientation, and head-nods. Body posture was less relevant in this interaction, as participants were sitting in comfortable chairs and hardly changed their body posture during the interaction. These behaviors are associated with empathy only if they are expressed immediately in response to the care-seeker's behavior. Eye-gaze time was coded when the care-giver was looking at the care-seeker, excluding times where the care-giver was speaking (Kappa = 97%). Smiling events were coded when the care-giver smiled towards the care-seeker in a relevant context (i.e. in response to the content of the conversation) (Kappa = 90%). Smiles directed towards the robot were not coded. Head-nod events were coded when initiated as a response to the care-seeker, and not when initiated with no clear association to the care-seeker's behavior (Kappa = 89%).

4.3.5 Verbal-Empathy

Care-giver's verbal-empathy remarks were identified based on the "verbal person centeredness" theory [5,21,70], arguing that high-quality verbal-empathy involves explicit acknowledgment and elaboration of the care-seeker's feelings. Accordingly, the verbal-empathy coding included comments that involved direct acknowledgment and affirmation of the care-seekers feelings as comforting messages, validation of the care-seeker's emotions, and direct attention to the care-seeker's feelings. We calculated the percentage of empathic remarks out of the overall number of remarks provided by the care-giver during the interaction, in order to control for individual differences in care-givers' general tendency to use verbal remarks (Kappa = 92%).

4.3.6 Perceived Stressfulness of the Problem

To validate that the interaction involves emotional support (and to balance the groups), participants were asked to rate the stressfulness of the problem they planned to disclose before beginning the interaction. Participants wrote a brief description of the problem they plan to disclose, and rated it along three 7-point scales; (a) stressfulness, (b) importance, and (c) pleasantness. Based on Collins and Feeney [31], the scales were summed to form an index of "perceived stressfulness of the problem". For each participant, we computed the a total score (Cronbach's Alpha = 0.79).

4.3.7 Attachment

To control for individual differences related to attachment orientations (anxiety, avoidance) that may affect the emotional support interaction [31], all participants completed a brief 12-item version of the well-known *experiences in close relationships scale* [19]. For each participant, we computed two total scores, reflecting his or her level of attachment anxiety and attachment avoidance (anxiety Cronbach's Alpha = 0.83, avoidance Cronbach's Alpha = 0.78). These scores were used as covariates in all quantitative analyses to evaluate the robot's effect regardless of participants' attachment orientations (anxiety, avoidance).

4.3.8 Impression of the Robotic Object

Although we focused on human–human–robot interaction and not human–robot interaction, we were interested in understanding if the robot's empathy-related behavior influenced participants' impression of the robot and its role during the emotional support interaction. We used three relevant sub-scales from the godspeed questionnaire: Likability (Cronbach's Alpha = 0.85), Animacy (Cronbach's Alpha = 0.68), and Perceived Intelligence (Cronbach's Alpha = 0.88)

[9]. The godspeed is a 5-item Likert scale questionnaire commonly used in HRI studies to test participants' impression of the robot.

In addition, we conducted a semi-structured interview to better understand participants' thoughts about the robot's role. The semi-structured interview was conducted with each participant immediately after the emotional support interaction in different rooms. The interview included specific questions concerning the robotic object (e.g. what did you think about the robotic object?) and a few general questions evaluating the emotional support interaction, (e.g. describe positive and negative aspects of the conversation). The interviews were transcribed and analyzed using Thematic Analysis [16,53], a qualitative analysis methodology commonly used in HCI and HRI. Two coders analyzed and rated the data, identifying repeating themes, comparing and contrasting their initial findings, until meaningful insights are generated. Our analysis included five stages: (1) Interviews were transcribed and half of the interviews (32 interviews) were read several times to develop a general understanding of the data before the coding process began; (2) Initial themes were identified, presented to a third researcher, and discussed in-depth until inconsistencies were resolved; (3) A list of mutually-agreed themes was defined; (4) The raters used mutually-agreed themes to analyze a selection of the data independently, verifying inter-rater reliability (Kappa = 91%); (5) following inter-rater reliability validation, the two raters analyze the rest of the data.

4.4 Procedure

The emotional support session was based on a paradigm designed by Collins and Feeney [31], adapted to interactions between friends. Upon arrival, participants were informed that they will participate in two emotional support sessions and that in each session one will disclose a personal problem, and the other will provide support. They were told that after the first session they will switch roles. Participants were informed that the conversation will be videotaped for research purposes, that their privacy is protected, that sensitive information will not be shared with anyone beyond the research team, and that all video materials will be erased when the analysis is complete. Participants were then informed that a robotic object will be present in the room, listening and moving. This initial introduction of the robotic object (before entering the experimental room) was designed to reduce the element of surprise and to set participants' expectations. Hence, before entering the room participants knew that a non-humanoid robot would accompany their conversation. Previous studies indicated that when participants are informed that they are about to take a part in an interaction, they apply human-to-human social scripts and set their expectations accordingly [44,46,114], however, when informed that they are about to interact with a robot, their expectations shift and they anticipate less social presence and experience increased uncertainty [46,114]. This is especially relevant when the robot has a non-humanoid appearance [44].

Following the robot's initial presentation participants signed a consent form and completed the attachment orientation questionnaire. They were then asked to choose a recent personal concern or worry (that does not involve their partner) that they feel comfortable sharing and to complete the "perceived stressfulness of the problem" questionnaire. The participants were then asked to enter a quiet room, commonly used for dyadic studies. The participant's chairs were placed with a precise 'conversation distance' of 76 cm between them (based on [20]). The robot was placed on a small table (46 cm in height; the height of the robot on the table was 77 cm) exactly between the two participants with a slight offset to reduce interference to participants' direct communication and eye contact (see Fig. 2).

As the participants entered the room, the researcher pointed to the robot and the WoZ controller triggered the "hello" sequence according to the protocol. The researcher verified that the participants saw the robot and noticed its movements. Participants were given time to get seated and to observe the robot's movement in order to reduce novelty effects and to set their expectations about the robot's capabilities. As the aim of the study was to evaluate the influence of the robot on emotional support, no further information concerning the robot was given to the participants. Next, participants were asked to begin the conversation where one of them (randomly chosen) disclosing a personal problem and the other reacting in a supportive manner. In the empathic-robot condition, the robotic object performed the "dominant turn" gesture towards the care-seeker, as the conversation began. This was followed by a 5 min session of "gaze-lean-nod 1" and "gaze-lean-nod 2" gesture sequences, activated according to the protocol designed based on the sessions with the therapist. The baseline-robot condition started in the same manner, followed by the robot performing the gentle "up-and-down" gesture sequence towards the space between the participants during the entire session. Each conversation session lasted 5 min and a knock on the door after 4 min signaled to the participants that one minute was left. At the end of the first session, participants were asked to complete the "subjective perceptions of the interaction" scale on a tablet device. As commonly done in psychological caregiving experiments and in order to assist participants in overcoming negative emotions, the care-seeker was asked to share a positive experience that occurred recently [11]. After this short positive interaction participants were asked to switch roles and repeated the interaction taking the other's role. At the end of the second session, participants were invited to a semi-structured interview in separate rooms. In the interview, the interviewer did not use any gendered pronouns when describing the robot

Table 2 Bayesian analysis of the interactions between the robot's behavior conditions, gender and first versus second interaction

Dependent measure	Interaction type Bayes factor	Bayes factor value (BF_{10})
Care-giver's subjective perceptions	Condition * Gender	0.19
	Condition * first versus second	0.14
	Condition * Gender * first versus second	0.07
Care-seeker's subjective perceptions	Condition * Gender	0.29
	Condition * first versus second	0.28
	Condition * Gender * first versus second	0.29
Interpersonal coordination	Condition * Gender	0.3
	Condition * first versus second	0.13
	Condition * Gender * first versus second	0.05
Duration of eye-gaze	Condition * Gender	0.15
	Condition * first versus second	0.3
	Condition * Gender * first versus second	0.05
Number of smiling events	Condition * Gender	0.28
	Condition * first versus second	0.18
	Condition * Gender * first versus second	0.06
Number of head-nod events	Condition * Gender	0.09
	Condition * first versus second	0.07
	Condition * Gender * first versus second	0.2
Verbal empathy	Condition * Gender	0.16
	Condition * first versus second	0.21
	Condition * Gender * first versus second	0.06

(e.g. He, She, or It), and used the term "Robotic Object" when referring to the robot. After the semi-structured interview participants completed the godspeed questionnaire and a demographic questionnaire. At the end of the experiment, we conducted a short conversation with each participant to verify that they were not left with any negative emotions.

5 Findings

We first analyzed the concerns participants discussed in the conversation as a manipulation check. The type of concerns discussed by the participants were achievement-related problems (24.4%) interpersonal problems (31.3%), and personal problems (45.3%). Some problems were coded into more than one category. On average, participants rated their problems as fairly stressful (mean = 5.6 , SD = 0.8 , on a 7-point scale). Thus, participants were discussing a variety of personally relevant and stressful problems. To verify that there is no dependency between the concern type and the robot conditions we conducted a Chi-square analysis. The insignificant result indicated an independence between the problem type and the robot conditions ($\chi^2_{(2)} = 1.55$, $p = 0.69$).

5.1 Quantitative Findings

All quantitative dependent measures were analyzed using a three-way ANCOVA for comparing the robot behavior conditions and their interaction with gender and first versus second interaction in the experimental session. The three-way analysis was performed in order to assess if the robot's influence was dependent on gender or on the first encounter with the robot (first vs. second interaction). Attachment ratings and previous acquaintances were used as covariates. No interaction was found between the robot's behavior conditions and the other variables (for any of the dependent measures). These null effects were further verified using Bayesian effects analysis [84] which revealed that all interactions with the robot's behavior conditions yielded Bayes factors equal or lower than 0.3, viewed as compelling support for the null model, (see [68,115], see Table 2). These null effects indicate that the impact of the robot's behavior was independent of gender or first versus second interaction.

5.1.1 Subjective Perceptions of the Interaction

A separate three-way ANCOVA analysis was performed for each of the two subscales. Care-seekers'subjective ratings of the emotional support provided by the partner were significantly higher in the empathic-robot condition, in

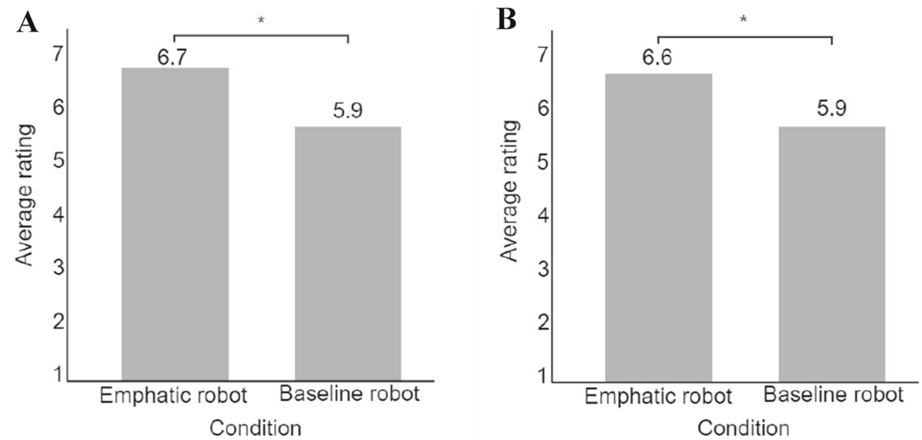


Fig. 4 Participants' subjective perception of the interaction: **a** care-seeker's subjective perception of the emotional support quality provided by the partner. **b** Care-giver's subjective perception of the emotional support quality provided by himself/herself

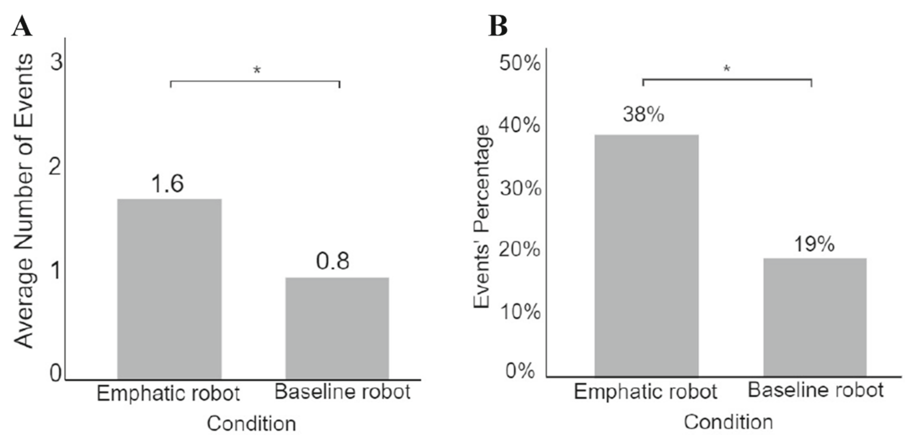


Fig. 5 **a** Average of interpersonal coordination events, specifically synchronization and mimicry, during the emotional support interaction. **b** The percentage of high-quality empathic remarks, out of the overall number of remarks provided by the care-giver during the interaction

which the robotic object performed empathy-related gestures towards the care-seeker, in comparison to the participants ratings in the baseline-robot condition, $F_{(1,53)} = 5.56$, $p = 0.02$, $\eta_p^2 = 0.1$ (see Fig. 4). The analysis also revealed a main effect for gender, with females reporting higher emotional support ratings, $F_{(1,53)} = 8.69$, $p = 0.005$, $\eta_p^2 = 0.13$.

A similar pattern was found in care-givers'perception of their own emotional support responses. Care-givers' subjective ratings of their own support was significantly higher in the empathic-robot condition in comparison to the ratings of participants in the baseline-robot condition, $F_{(1,53)} = 5.24$, $p = 0.03$, $\eta_p^2 = 0.09$ (see Fig. 4). This analysis also revealed a main effect for gender, with females reporting higher emotional support ratings, $F_{(1,53)} = 5.09$, $p = 0.03$, $\eta_p^2 = 0.08$.

5.1.2 Interpersonal Coordination

Interpersonal coordination was also significantly influenced by the behavior of the robotic object. Interpersonal coordination events were significantly more frequent in the empathic-robot condition in comparison to interpersonal coordination events in the baseline-robot condition $F_{(1,53)} = 16.04$, $p < 0.001$, $\eta_p^2 = 0.25$ (see Fig. 5).

5.1.3 Verbal Empathy

The percentage of verbal-empathy remarks was also significantly influenced by the behavior of the robotic object. Care-givers' verbal-empathy remarks were significantly more frequent in the empathic-robot condition in comparison to the baseline-robot condition, $F_{(1,53)} = 7.06$, $p = 0.01$, $\eta_p^2 = 0.12$ (see Fig. 5).

5.1.4 Non-verbal Immediacy

Three non-verbal behaviors were analyzed as indication for the care-giver's non-verbal immediacy: the duration of eye-gaze towards the care-seeker, number of smiles towards the care-seeker, and head-nod events. The robotic object's behavior influenced both duration of eye gaze and number of smiles, but did not influence the number of head-nod events. Care-givers' eye-gaze duration towards the care-seeker was significantly longer and they smiled more often in the empathic-robot condition in comparison to the baseline-robot condition, $F_{(1,53)} = 4.25$, $p = 0.04$, $\eta_p^2 = 0.08$; $F_{(1,53)} = 6.57$, $p = 0.01$, $\eta_p^2 = 0.11$ respectively (see Fig. 6).

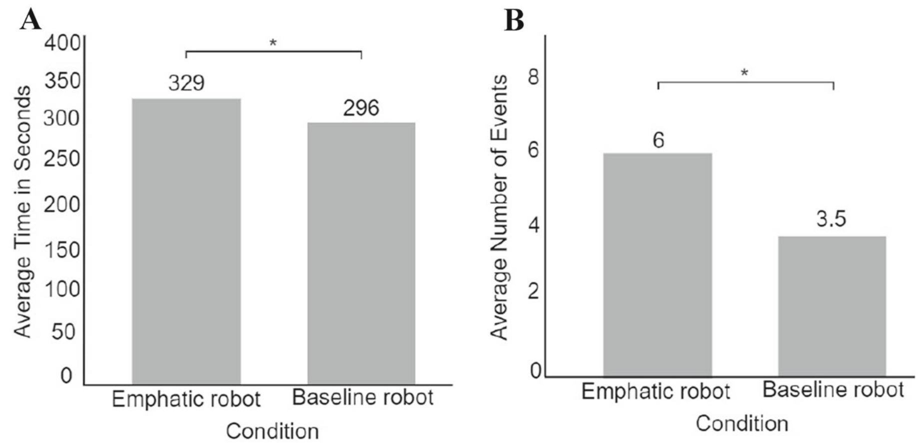


Fig. 6 **a** The total duration of care-giver's eye gaze towards the care-seeker. **b** Average number of smiles towards the care-seeker

Table 3 Number of participants associating a role with the robot in each condition

	Empathic-robot	Baseline-robot
Supportive	13/32	3/32
Conversation-mediator	3/32	2/32
Uninvited eavesdropper	4/32	7/32
Robot-insignificant	12/32	20/32

5.1.5 Robot's Perception

The participant's perception of the robot was evaluated using the three subscales of the godspeed questionnaire (likability, animacy, intelligence) and qualitative analysis of responses to the semi-structured interview.

The analysis of the godspeed subscales revealed no significant differences in any of the scales. The qualitative analysis of the interviews indicated that the perception of the robot's behavior varied between participants, and between conditions.

Participants associated the robot's behavior with one of the following themes: *supportive robot*, *conversation mediator robot*, *uninvited eavesdropper robot*, or *robot insignificant*. See details about each theme below, and a summary of the number of participants reporting each theme in Table 3.

Supportive Robot 13/32 participants in the empathic-robot condition and 3/32 in the non-empathic baseline-robot condition perceived the robotic object as supportive. The "supportive robot" theme included responses that describe the robot as caring and calming "He is nodding, indicating that he understands me" (p. 37; empathic-robot) "He is a calming object" (p. 26; empathic-robot). Participants suggested that the robot's role is to provide a sense of security and attention "He was listening to us and his role was to make you feel safe, making sure you feel that someone is listening to you" (p. 3; empathic-robot). Participants' also mentioned how the robot made them feel "I felt that he was here and he created a pleasant atmosphere as if everything is alright" (p. 35; baseline-robot). Some participants even suggested using the robotic object for reducing stress in sensitive human–human interactions "If you go to a psychologist and you are stressed about it, there is something else in the room that is not judging you" (p. 3; empathic-robot).

Insignificant 12/32 participants in the empathic-robot condition and 20/32 participants in the non-empathic baseline-robot condition stated that the robotic object did not influence the interaction, and treated it as insignificant "The conversation would be exactly the same with it or without it" (p. 2; baseline-robot). Participants explicitly stated that the robot had no effect over the interaction "It wasn't disturbing nor helpful" (p. 20; baseline-robot), and found it useless "It didn't do anything" (p. 10; empathic-robot). In some cases, they stated that they did not notice the robot "I kind of forgot about it" (p. 30; empathic-robot), and explained their lack of attention to the robot by the attention required in the emotional support interaction "I was so focused on her [the partner] making sure I am listening to what she says" (p. 4; empathic-robot).

Uninvited Eavesdropper Robot 4/32 participants in the empathic-robot condition and 7/32 in the baseline-robot condition perceived the robotic object in a negative way, as an uninvited eavesdropper "There was something moving and looking at you the whole time, it made me feel a little nervous" (p. 19; baseline-robot). They stated that the robot's presence invaded the conversation's privacy "It was creepy, it felt that there was less privacy as if someone is here moving around" (p. 5; empathic-robot). They stated that it made them feel that there was another presence, disturbing the intimacy between them and their partner "It wasn't just a conversation with my friend, there was someone else there all the time" (p. 27; baseline-robot).

Conversation Mediator Robot 3/32 participants in the empathic-robot condition and 2/32 in the baseline-robot condition perceived the robotic object as a mediating object, one that is responsible for regulating the conversation and the human–human interaction. They stated that the robot's role was to indicate who should be talking and when to begin "As if somebody points at you and saying it's your turn" (p. 6; empathic-robot). Others suggested that its role was to influence and improve emotional support interactions by influencing the care-giver's behavior and suggested health context as an example "It will influence the care-givers leading them to moderate their responses and to understand the patient" (p. 18; baseline-robot). One participant even suggested that the robot will make people open-up more than a therapist will "Sometimes couples feel embarrassed in front of a psychologist. Maybe they will share much more in front of a robot" (p. 25; empathic-robot).

6 Discussion

In this work we showed that a robotic object performing empathy-related gestures can significantly improve the quality of a human–human emotional support interaction involving two friends. Emotional support is one of the most important human–human interactions, known to have a significant influence on well-being [22,80,88]. The robot's emphatic gestures increased both objective and subjective emotional support quality, when compared to the baseline non-empathic behavior performed by the exact same robotic object. This effect was evident despite the robot's non-humanoid appearance and its limited communication capabilities. The robot's behavior that led to the improvement in interpersonal human interaction was modeled by a human expert that emphasized lean, gaze, and nod gestures towards the care-seeker. The impact of the robot on the HHI may suggest an advantage for robots' gestures that are modeled based on a grounded design process that draws from interactions with professional care-givers.

This work extends prior empathy-related HRI work by using a non-humanoid robot to enhance the perceived emotional support provided by a human care-giver, instead of replacing the human care-giver by an empathic robot. While previous HRI studies used a robot as the emotional support provider, in this study the robot enhanced emotional support provided by another human. Results show that participants indeed attribute the increase in emotional support quality to the other human (the care-giver), indicating that a robot can enhance the way two humans interact without replacing or competing with the care-giver's role.

The study also extends prior HHRI work by evaluating the way humans perceive one another (i.e., interpersonal evaluation) in the context of emotional support, an intimate interaction that involves empathy. The empathic robot significantly increased the care-seeker's subjective perception of the emotional support quality provided by the care-giver in the interaction. This subjective effect is considered to be the most important aspect of the emotional support interaction, as the care-seeker's perception of the emotional support quality has been found to be more important than the actual support provided in the interaction [61,127]. The robotic object also increased care-givers' subjective perception of their own emotional support quality.

Apart from the effect on the subjective perception of emotional support quality (both by the care-seeker and care-giver), the robot also influenced the care-giver's actual behavior (as indicated by objective measures). Non-verbal immediacy, interpersonal synchronization, and verbal empathy were all significantly improved when the robot modeled empathic behavior. This effect indicates that the robot's empathy-related gestures affected more than just the care-seeker's subjective perception. The empathic robot improved the actual support provided by the care-giver, leading to an increase in empathy-related behaviors. While this increase could be attributed to the modeling of appropriate behaviors by the robot, our findings suggest an even greater impact. The robot modeled lean, gaze, and nod behaviors, however, the human care-givers performed a variety of empathy-related behaviors including verbal empathy, smiling, and interpersonal coordination. These behaviors were not modeled by the robot. A possible explanation for this extended effect can be attributed to a priming effect, where the robot's empathic behavior primed care-givers' empathic reactions, activating responses and behaviors that enhance emotional support quality. This finding highlights the advantage of robotic non-verbal communication in a human–human interaction context, which empowers human–human interaction rather than replacing it with human–robot interaction.

Most participants were not aware of the robot's influence on their behavior, reporting the robot to be non-intrusive and even meaningless "I kind of forgot about it" (p. 30; empathic robot). They also found the robot to be peripheral to the interaction "In the beginning I looked at it a bit and then, we just talked" (p. 15; empathic robot). Participants accepted the robot as a side-participant in their conversation (defined as taking part but not being addressed [27,54]), indicating that the natural flow of human–human emotional support interaction was preserved and that the robot's presence did not compromise or overshadow it. It is possible that the robot's non-humanoid design contributed to this effect, as well as the limited communication modalities, and subtle non-verbal gestures as the only form of interaction. Additional possible aspects include the robot's small size, plain color, and non-dominant form [135]. Some participants (11/64) did find the robot's behavior to be unpleasant and even intrusive. This was more frequent in the baseline-robot condition (7 participants) and implies that when a robot is not well-integrated into the context of HHI, some people (who are probably more sensitive to peripheral interference in their immediate environment) would reject the robot as a valid side-participant to their conversation.

One point that should be further studied in future work concerns the different aspects of the robot's influence. The care-seeker's perception of the emotional support quality provided by the care-giver could have been affected by two aspects of the robot's influence. First, the robot's influence on the care-giver's empathy-related behavior, and second, the robot's direct influence on the care-seeker's subjective perception of the emotional support provided in the interaction. It is possible that the robot's empathic behavior influenced the care-seeker who in turn attributed the effect to the human care-giver instead of to the robot. Thus, it is possible that the HRI influenced the HHI. If this is the case, the effect was implicit, as no differences were found in the godspeed ratings between conditions (evaluating the human perception of the robot). In addition, the qualitative analysis revealed that less than half of the participants in the empathic-robot condition (13/32) defined the robot's non-verbal gestures as indicating empathy.

Another point that should be considered is the lack of interaction between the robot's influence and gender. Gender typically influences psychological caregiving ratings [89,104,123], which was also evident in the subjective emotional support measures used in this study. Self-report measures of emotional support, commonly indicate higher ratings of perceived support by women participants in comparison to men [123]. This well-known gender effect did not interact with the robot conditions, indicating that the robot's behavior had a similar effect on the perceived support of both men and women.

More broadly, our findings provide support for the possibility of using a robotic object as a communicator in an interaction with humans as suggested by HMC studies [58–60]. Specifically our study indicates that a robot can be integrated as a communicator in intimate and sensitive interactions that involve more than one human. We extend the HMC literature by introducing a minimal form of communication applied by simple non-verbal gestures of a non-humanoid robot. The robot's role in the communication formed a new meaning not just in the context of HRI but also in the context of HHI. The robot enhanced the meaning of the human–human interaction and improved the communication between humans, without altering its nature. In addition, our findings support Gambino et al.'s [51] claim that interactions that involve HMC may lead to the development of novel social scripts and to update existing mental models that humans use when communicating with others. These new social scripts are derived based on the social affordances of the technology. The robotic object used in this study was designed to be peripheral to the interaction and in many cases, its minimal gestures led to an implicit influence that was hardly noticed by the participants. This may suggest that peripheral non-humanoid robots that perform minimal gestures can take the role of implicit facilitators in human–human interactions. This role (i.e. implicit facilitator) does not comply with common human social scripts and therefore creates a new model of communication that is relevant for the interaction with robots (and not humans).

To conclude, our findings contribute to the emerging field of human–human robot interaction research, by showing that carefully-designed non-verbal gestures of a non-humanoid robotic object can successfully influence an intimate human–human interaction such as emotional support. The robotic object's behavior and specifically lean, gaze, and nod gestures, enhanced participants' subjective evaluation of the interaction and improved their ability to provide emotional support as care-givers. This supportive behavior extended beyond the behavior modeled by the robot. The robot's limited non-verbal cues successfully influenced the objective and subjective aspects of the interaction and triggered non-modeled empathy-related behaviors. The robot's design did not lead to false expectations and possibly contributed to the perception of the robot as peripheral to the conversation, thus preserving the natural flow of the intimate interaction. Our results indicate that the implicit influence of a peripheral robot can enhance HHI, suggesting that robotic objects may be ideal candidates for enhancing human–human interpersonal interactions. We therefore present an additional perspective for HRI, where robots are used for facilitating HHI instead of replacing one of the humans in the interaction. From an ethical perspective, our findings show that most participants were not aware of the effect the robot's behavior had on their own behavior (a positive effect in our case). Since the implicit influence of robots' non-verbal behavior can be used inappropriately in various contexts, from social interaction to decision making, we call the new field of HHRI to follow the ethics agenda promoting technical innovation while respecting human values [100,101].

7 Limitations and Future Work

Caregiving is a complex interaction that can take many forms. We focused on a common emotional support interaction involving two friends of the same gender. The specific choice of same-gender friends was intended to reduce the influence of factors such as gender roles and different types of relationships. Future work should assess additional forms of emotional support interactions, including couples and parent-child interactions. In addition, emotional support interaction can also take place between strangers (e.g. doctor appointment). Due to ethical reasons, we decided to avoid a situation where one participant is required to share a personal problem with a stranger. Another limitation concerns the duration of the interaction. The emotional support interactions in the study were limited to 5 min, based on the therapist's recommendation, suggesting that 5 min are sufficient for sharing a meaningful personal problem and providing high-quality emotional support. However, many emotional support interactions are longer and involve more detailed discussions, suggesting that the robot's influence over time should be further explored. Another related limitation is the novelty effect and habituation. It is possible that over time, the robot's non-verbal gestures will not influence the emotional support quality due to habituation. Notably, the robot's effect was implicit and participants were not aware of the robot's influence on their behavior, implying that the novelty effect is less relevant. The specific design of the robotic object used in this study should also be further explored in order to identify the robotic features that contributed to the positive effect on emotional support, including the robot's size, shape, and gesture design.

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Declarations

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