HUMAN–COMPUTER INTERACTION
https://doi.org/10.1080/07370024.2020.1719839

Human-human-robot interaction: robotic object's responsive gestures improve interpersonal evaluation in human interaction

Danielle Rifinski[a], Hadas Erel[a], Adi Feiner[a], Guy Hoffman [b], and Oren Zuckerman[a]

[a]Interdisciplinary Center (IDC) Herzliya, School of Communications, Herzliya, Israel; [b]Cornell University, Sibley School of Mechanical and Aerospace Engineering, Ithaca, New York, USA

KEYWORDS Collaboration Tools; Ubicomp; Human-Robot Interaction; Interpersonal Evaluation; Human-Human-Robot Interaction; Social Robots; Conversation Quality
ARTICLE HISTORY Received 8 February 2019; Revised 19 January 2020; Accepted 19 January 2020

1. Introduction

Robots designed for social interaction are predicted to be employed in a wide range of environments including homes, schools, and workplaces (Bartneck & Forlizzi, 2004; Fong, Nourbakhsh, & Dautenhahn, 2003; Forlizzi, 2007; Pacchierotti, Christensen, & Jensfelt, 2006; Tanaka & Ghosh, 2011). Most studies evaluating robots for social interaction focus on the direct interaction between the human and the robot, typically the interaction between one human and one robot (Foster et al., 2012; Hoffman, Bauman, & Vanunu, 2016; Luria, Hoffman, & Zuckerman, 2017; Mwangi, Barakova, Diaz, Mallofré, & Rauterberg, 2017; Zaga, de Vries, Li, Truong, & Evers, 2017), or the interaction between a group of humans and one robot (e.g. Groom & Nass, 2007). In recent years there has been a growing interest in the effect of social robots, not only on the human-robot interaction, but also on the human-human interaction in the presence of a robot. This emerging subdomain is framed by some as human-human-robot interaction (HHRI) (Forlizzi, 2007; Jung, Martelaro, & Hinds, 2015; Mutlu, Shiwa, Kanda, Ishiguro, & Hagita, 2009).

Human-human-robot interaction has been studied in the context of home environments (Forlizzi, 2007; Fukuda, Jung, Nakashima, Arai, & Hasegawa, 2004; Spexard et al., 2006), conflict resolution (Jung et al., 2015; Shen, Slovak, & Jung, 2018), turn-taking (Mutlu et al., 2009), human relationships (Sakamoto & Ono, 2006), and group interactions (Groom & Nass, 2007). This prior research addressed the robot's influence on family dynamics (Forlizzi, 2007), the robot's influence on emotion regulation (Jung et al., 2015), the robot's ability to control the interaction (e.g. Mutlu et al., 2009), and participants' evaluation of the robot in the human-human context (e.g. Hoffman et al., 2016). In contrast to previous work, in this study we test the effect of the robot's gestures on the way people perceive each other, by measuring human-human interpersonal evaluation.

The robot's influence is evaluated in the context of face-to-face conversation, a common and important aspect of human-human interaction that has been extensively studied in social science (Clark, 1996; Emmers-Sommer, 2004; Goffman, 1979, 1981; Mohr & Spekman, 1994; Verplanck, 1955). The roles people take in conversation are defined as ratified participants (involved in the conversation) and unratified participants (overhearers) (Clark, 1996; Goffman, 1979) (See Figure 1). Ratified participants are further defined as speaker, addressee, and side-participants. Side-participants can be a part of a conversation with more than two participants and are considered as the "unaddressed recipients" of the speech, hence, they are not addressed but are considered to be a part of the current conversation. Side participants is defined as having rights and responsibilities

CONTACT Oren Zuckerman orenz@idc.ac.il Interdisciplinary Center (IDC) Herzliya, 8 University St Herzliya, P.O.Box 167, 460101, Israel

Supplemental data for this article can be accessed at www.tandfonline.com/loi/hhci20. The supplementary data includes the items taken from the Relational Communicational Scale; Items taken from the Liking Scale; The questions used in the semi-structured interview.

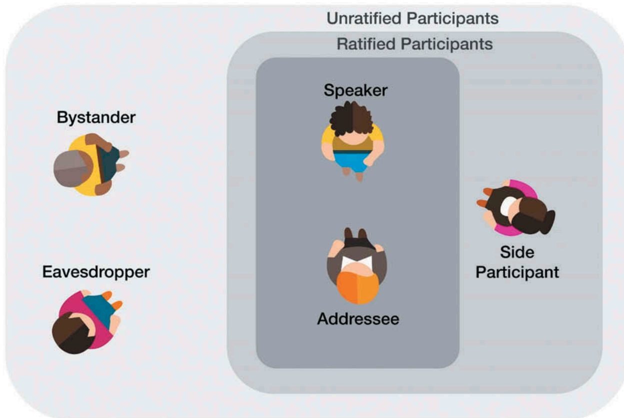


Figure 1. Participation Structure: different types of participants in a multi-party conversation, adapted from Clark (1996) and Mutlu et al. (2009).

within the conversation even though they are not speaking. The speaker is not addressing the side participant but is responsible for ensuring that the side participant follows the conversation even if he/she is not required to respond. Unlike side participants, unratified participants are defined as non-participants, either "bystanders" or "eavesdroppers" which observe the conversation in the background without participating in it (Clark, 1996; Goffman, 1979, 1981; Matsuyama et al., 2015). Unratified participants have no rights or responsibilities in the conversation and the speaker is not obliged to consider them (Matsuyama, 2015).

The quality of conversation has been found to affect a variety of important social aspects associated with successful partnerships (Mohr & Spekman, 1994), including relational satisfaction, partnership attributes of commitment, involvement, and trust (Emmers-Sommer, 2004; Mohr & Spekman, 1994; Verplanck, 1955). Conversation quality has thus been of interest to human-human relationship researchers.

Within this literature, one of the constructs shown to predict the quality of conversation is the participants' interpersonal evaluation (Emmers-Sommer, 2004). The effect that interpersonal evaluation has on conversation quality is often explained by the ratified participants' attention to each other (Taylor & Fiske, 1978). Attention is indicated through verbal and nonverbal communication channels, with the most significant ones being speech, gaze, and leaning gestures (Goodwin, 1981; Vertegaal et al., 2001). Gaze and leaning typically indicate participants' attitudes toward the topic discussed, and the level of agreement with the attitudes of other participants (Breed, 1972; Bull, 2016). Moreover, gaze directed toward ratified participants also leads to a positive evaluation of competence, friendliness, credibility, assertiveness, and social skills (Kleinke, 1986).

To summarize the theoretical background of this work, the literature indicates that in the context of a conversation, gaze and leaning are nonverbal behaviors that signal mutual attention which in turn can influence participants' interpersonal evaluation (Otsuka, Yamato, Takemae, & Murase, 2006), leading to higher conversation quality and positive relationship outcomes. In this work, we evaluate the effect of a robot's gaze and leaning gestures on human conversants' interpersonal evaluation.

Gaze and leaning gestures are common in human-robot interaction (HRI) studies (Han, Campbell, Jokinen, & Wilcock, 2012; Henkel, Bethel, Murphy, & Srinivasan, 2014; Luria, Hoffman, Megidish, Zuckerman, & Park, 2016; Mutlu, Kanda, Forlizzi, Hodgins, & Ishiguro, 2012; Robins, Dautenhahn, Te Boekhorst, & Billard, 2005; Takayama & Pantofaru, 2009; Vázquez et al., 2017). Prior work indicates that gaze and leaning gestures, which are some of the most basic nonverbal behaviors a robot can perform, are consistently interpreted as social cues even when they are performed by non-humanoid robots (Beck, Cañamero, & Bard, 2010; Hoffman & Weinberg, 2011). Non-humanoid robots are believed to have several advantages that make them leading candidates for social interaction in daily contexts. Non-humanoid robots are mechanically simpler, have fewer Degrees of Freedom (DoF), are more reliable and therefore are easier to control and cheaper to manufacture (Parlitz, Hägele, Klein, Seifert, & Dautenhahn, 2008). These robots can also overcome some challenges related to humanoid robots including unrealistic expectations and the "Uncanny Valley" effect (Duffy, 2003; Hoffman & Ju, 2014; Mori, 1970; Parlitz et al., 2008). In addition, from a design perspective, taking away the constraint of a human-like figure allows flexibility and freedom for the designer (Hoffman & Ju, 2014). At the same time, non-humanoid robots also present a challenge. The simple design and mechanical implementation limit the robot's communication modalities and prevent mimicking complex human social cues. Therefore, most of the communication is typically designed using limited physical gestures (Bethel & Murphy, 2010; Gemeinboeck & Saunders, 2017; Hoffman, Zuckerman, Hirschberger, Luria, & Shani Sherman, 2015; Luria et al., 2017; Zaga et al., 2017; Zuckerman & Hoffman, 2015). As non-humanoid robots are believed to become more common due to the above-mentioned advantages, the influence of their gestures on humans' interpersonal evaluation is becoming a key question. This work focus on physical gestures of non-humanoid robots, and specifically on minimal responsive gestures. The non-humanoid design of the robot provides a research platform for testing the effect of minimal gestures independently of factors such as voice communication, human-like appearance, or other communication modalities.

In this study, we tested whether gaze and leaning gestures of a non-humanoid robotic object have an effect on the human participants' interpersonal evaluation, in the context of a conversation. We evaluated the effect of the robot's behavior on the participants' perceptions of each other, regardless of their perception of the robot. The robotic object was presented as a ratified side-participant in a face-to-face conversation between two people, and its influence was tested in three conditions: 'Responsive to Speaker', 'Responsive to Addressee', or 'Non-responsive'. Our findings indicate that the two responsive conditions lead to significantly higher ratings of interpersonal evaluation of the human conversation partner.

2. Related work

The majority of studies in the emerging field of HHRI evaluated the interaction between humans and a robot in the context of human-human interaction (Bohus & Horvitz, 2014; Correia, Mascarenhas, Prada, Melo, & Paiva, 2018; Oliveira et al., 2018; Tan, Vázquez, Carter, Morales, & Steinfeld, 2018). Only a few studies tested the robot's effect on the interaction between the humans. Forlizzi's (2007) pioneering work compared the effect of two vacuum cleaners on the social dynamics of household members. The comparison between the Roomba vacuum-cleaner robot and the Flair traditional handheld stick vacuum revealed that the Roomba robot affected family dynamics, making cleaning a concern of all household members (Forlizzi, 2007). Robotic objects were also integrated in a group context. Jung et al. (2015) showed that a robot can improve emotion regulation, and positively influence conflict resolution during a team-based problem-solving task (Jung et al., 2015). Similarly, Shen et al. (2018) showed that robots can improve children's conflict resolution ability when the robot provided prompts relevant to the conflict. Robots were also shown to assist in group stress reduction, team coordination, and team performance (Shah, Wiken, Williams, & Breazeal, 2011).

Studies that tested HHRI in a conversation context typically focused on technical challenges of role assignment, evaluating the robot's ability to identify the speaker and listeners, and its ability to estimate "who is the next speaker" (i.e. turn taking) (Bohus & Horvitz, 2014; Matsusaka, Fujie, & Kobayashi, 2001; Matsuyama, Taniyama, Fujie, & Kobayashi, 2010). Only a few studies evaluated social aspects of HHRI in a conversation context. Mutlu et al. (2009) demonstrated how a non-verbal cue, such as the robot's gaze, can influence participants' roles and turn-taking in a human-human-robot conversation context (Mutlu et al., 2009). The robot's gaze had a profound influence on the number of turns taken by each participant and the time spent speaking, indicating that a robot can influence the dynamics of a conversation. However, the study did not evaluate the robot's influence on participants' evaluation of each other, i.e. their interpersonal evaluation. Another study that evaluated HHRI in the context of a conversation was performed by Hoffman et al. (2015), who tested participants' evaluation of a robotic object in a couple conversation context. When the robot was responsive to the conversation and performed relevant gestures, participants were more attentive to the robot, in comparison to a robot that moved but was not responsive to the conversation (Hoffman et al., 2015). Additional studies that evaluated factors influencing the inclusion of a robot in a conversation, indicated that beyond responsiveness, the robot's function and gestures (e.g. orientation and gaze) are important for natural integration of a robot in HHI conversation context (Sidner, Lee, Kidd, Lesh, & Rich, 2005; Vázquez et al., 2017).

Of special relevance to this work, Tennent, Shen, and Jung (2019) tested the influence of a non-humanoid robotic object on conversational dynamics and performance in small groups. The robotic object is reminiscent of a microphone (Micbot) and used non-verbal backchanneling behavior, designed to promote participants' engagement and performance in a group problem solving activity. The robotic object's responsive movements led to more balanced group conversational dynamics by increasing the participation of the more passive group members and promoting additional backchanneling behavior. The participants' increased engagement eventually resulted in improved problem-solving performance by the group members (Tennent et al., 2019). While this work evaluates the influence of a peripheral non-humanoid robot on HHI, it focuses on group dynamics and problem solving and does not evaluate the robot's influence on the participants' interpersonal evaluation.

This paper extends Hoffman et al. (2015), which evaluated participants' perception of a robotic object in human-human conversation context (Hoffman et al., 2015). In the current study, we used the same low DoF non-humanoid robot (See Figure 2) used by Hoffman et al. (2015; see also

Figure 2. The robotic object used in the study; a 2 degree-of-freedom non-humanoid robot called Kip.

Zuckerman & Hoffman, 2015). Unlike prior work, we tested the robot's influence on participants' interpersonal evaluation (regardless of their perception of the robot). To the best of our knowledge, this study is the first to measure the effect of robot responsiveness on human-to-human interpersonal evaluation. We compared three robot conditions: (1) 'Responsive to Speaker'; (2) 'Responsive to Addressee'; and (3) 'Non-responsive' (baseline).

3. Robot design & implementation

The robot used in this study was Kip, a small non-humanoid robotic object reminiscent of a desk lamp. Previous studies using the same robot (Hoffman et al., 2015) indicated that the movement of the upper part of the robot was perceived by participants as gaze, despite its non-humanoid form that does not include a human-head and facial features such as eyes. Throughout the paper, we will use the term gaze when the robot's top part is moving toward participants. The robot is equipped with two motors: a base motor, which controls horizontal rotation motion to support the robot's lateral gaze movement, and a body motor, which controls the vertical motion to support the robot's lean movement (See Figure 2). The gestures performed by the robot were previously shown to be interpreted as indicating the robots' emotions and intent (Erel, Hoffman, & Zuckerman, 2018; Hoffman et al., 2015). We slightly updated the set of robot behaviors that were used in previous studies (Hoffman et al., 2015) to match our study goals (See Figure 3 for the new behaviors descriptions and parameters). The robot's gestures were triggered using the Wizard-of-Oz (WoZ) technique, a common method in HRI (e.g. Mutlu et al., 2012; Riek, 2012), to help us maintain experimental control over the behavior of the robotic object.

The robot's software system is comprised of two parts (Figure 4). The first is a desktop Java application that runs the WoZ module; it enables an operator to select the robot's gestures from a control room using a graphical user interface. The second part is an Android application called Behavior Controller (BC), which runs an HTTP server, which listens to requests and executes the robot's gestures. The Android device running this module is connected via a USB cable to a micro-controller board which directly drives the robot's motors.

Upon selection by the experimenter in the control room, the WoZ module sends HTTP requests to the BC specifying a behavior from the BC's library of stored behaviors. A *behavior* is internally defined as a sequence of *gestures* each defined by two parameters: (1) an end-goal position for the two motors (in radians); and (2) the duration for the two motors to reach the end-goal position. When a behavior is triggered, each gesture is translated into a timed sequence of motor commands, which are sent to the robot through the micro-controller board.

4. Method

4.1. *Participants*

60 undergraduate students from Communications, Psychology, and Computer Science departments participated in the study (33 female, 27 male; M = 25.1, SD = 2.45). Participants were recruited in pairs and reported their level of acquaintance from 1 (no previous acquaintance) to 5 (strong friendship) (1–13.3%; 2–3.3%; 3 – 23%; 4–30.3%; 5 – 30%). Participants who couldn't find a pair were assigned to a partner by the researcher. To verify that 'level of acquaintance' was balanced between the three conditions, we used a matching technique. Gender was also balanced between conditions with 5 mixed pairs and 5 non-mixed pairs in each condition (3 female pairs and 2 male pairs in each condition). Students received extra course credit for their participation and signed a consent form.

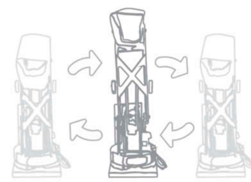
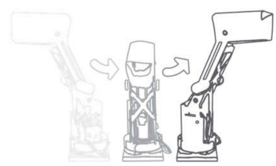
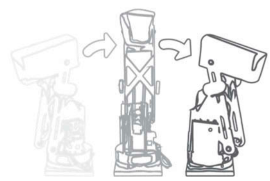
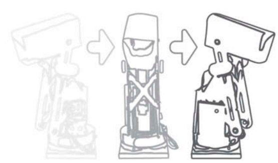
Behaviors	Description	Duration (in seconds)	Interval (in seconds)	Image
Non-responsive	Moving up and down slowly and repeatedly, as if "breathing" in place, no gaze towards any of the participants, always "facing" the center between both participants	3	3	
Responsive to Speaker	Gaze and lean towards Speaker	2	2	
Responsive to Addressee	Gaze towards Addressee and no-lean.	2	2	
Responsive to Interrupter	In case of an addressee interruption (according to protocol), it turns towards the addressee and then returns to its position	2	2	

Figure 3. Behaviors description. All responsive gestures were animate in their end position, via a slight back and forth movement.

4.2. *Experimental design*

In this between-participant study, different participants were randomly assigned to the three experimental conditions. The robotic object was a side-participant in a conversation (a ratified participant in the conversation that is not addressed; See Figure 5). The robotic object could perform different combinations of the following gestures: Gaze gesture (gaze is approximated by the orientation of the robot's head); Leaning gesture (where the robot leans toward the participant); Breathe-like gesture (up and down movement in a slow repetitive way).

In order to test the influence of the robot's behavior (gaze and leaning) on participants' interpersonal evaluation during a conversation, we designed two responsive conditions and one baseline 'Non-responsive' condition. In the first responsive condition, the robotic object was 'Responsive to

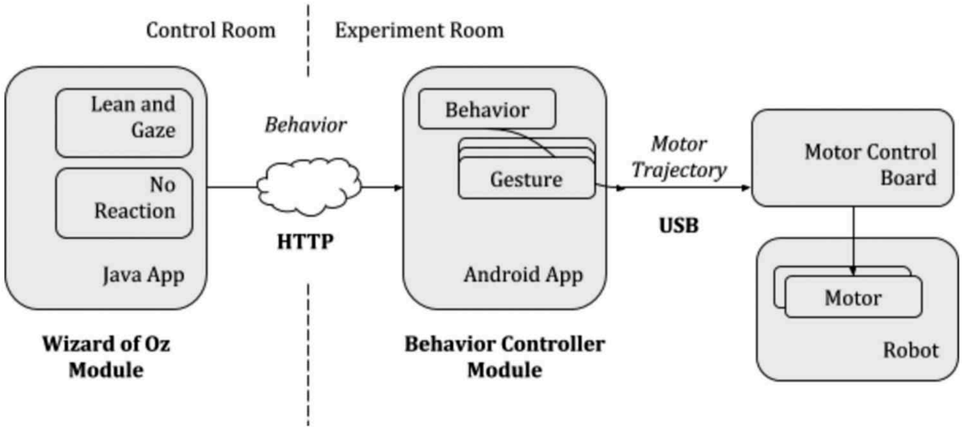


Figure 4. System diagram: the Java application (WoZ module, left) sends an HTTP request from the control room to the Android App (Behavior Controller module) in the experiment room. This selects a behavior from the library and generates the sequence of gestures in the form of motor trajectories. These are used by the motor control board, connected via USB to the Android device to drive the robot's motors.

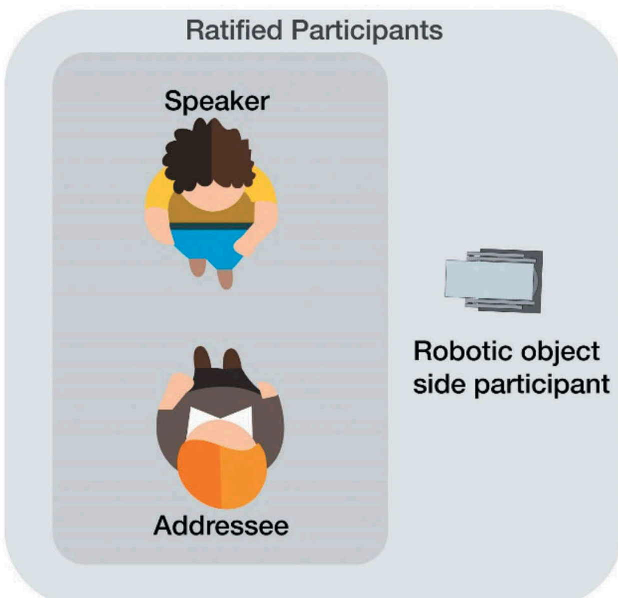


Figure 5. The robotic object was introduced as a side-participant in the conversation.

Speaker' (gaze and lean toward the speaker). The robot's behavior was designed according to common norms for side-participants in a conversation (Vertegaal et al., 2001). In the second responsive condition, the robotic object was 'Responsive to Addressee' (gaze toward the addressee and no-leaning). This condition was designed to explore a robot's behavior that represents a much less common behavior in conversations, but one that can still occur (Kendrick & Holler, 2017; Vertegaal et al., 2001). In the baseline condition the robotic object performed 'Non-responsive' movements, an up and down movement in a slow repetitive way, as if it was "breathing" gently, "facing" the center of the space between the participants, without attending any of them (See Figure 6 for an illustration of the three conditions). The baseline condition was chosen after careful

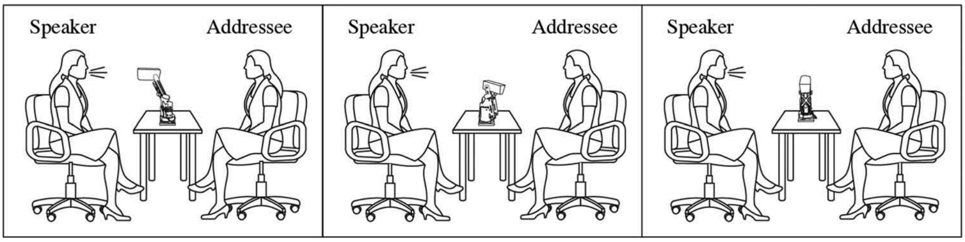


Figure 6. Three conditions (from left to right): robotic object 'Responsive to Speaker', robotic object 'Responsive to Addressee', robotic object 'Non-responsive' (baseline).

consideration of possible confounding variables. The main considerations included the concern that using a random baseline may lead to a variance in the participants' social interpretation of the gestures and reduce the control over the interpretation of robot's non-responsive behavior (which may be considered partly responsive in a random condition). Another option for baseline was a non-moving robotic object. However, using this baseline would limit the possibility to claim that the responsive behavior contributed to the effect, and not the mere movement of the robot.

4.3. *Measures*

We utilized both quantitative and qualitative measures, including three scales, a non-verbal measurement of participants' interpersonal evaluation, and a qualitative post-experimental interview.

4.3.1. *Quantitative dependent measures*

The quantitative measures included the 'Relational Communicational Scale' (Burgoon & Hale, 1987; Burgoon & Koper, 1984) for evaluating interpersonal evaluation in the context of a conversation (Cronbach's α: 0.88); the 'Human-Human Liking Scale' (Maxwell, Cook, & Burr, 1985) for assessing participants' liking aspect of interpersonal evaluation (Cronbach's α: 0.94); and the 'Godspeed Questionnaire' (Bartneck, Kulić, Croft, & Zoghbi, 2009) for the robot evaluation (Cronbach's α: 0.90).

4.3.1.1. *Relational communicational scale.* For testing interpersonal evaluation in the context of a conversation, we applied the 'Relational Communicational Scale', which was designed to measure interpersonal interchanges (Burgoon & Hale, 1987; Burgoon & Koper, 1984). The questionnaire is divided into eight subscales. For this study, we chose the five subscales that were applicable to the human-human conversation context: (1) Similarity; (2) Social Orientation; (3) Non-immediacy; (4) Intimacy; and (5) Arousal. The subscales included items such as: *"He/She tried to establish good relations"*, *"He/She was sincere"*, *"He/She didn't care if I liked him/her"*, *"He/she was bored by the conversation"*. Participants rated the items on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). See supplementary material for the full scale.

4.3.1.2. *Human-human liking scale.* The 'Human-Human Liking Scale' was applied to measure participants' perceived similarity and mutual liking (Maxwell et al., 1985). In line with our research question, this scale measures participants' liking level for each other, rather than their liking for the robot. The scale includes items such as: *"I feel that my conversation partner is a very likable person"*, *"I believe that I would very much enjoy talking to my conversation partner again"*, *"My conversation partner and I just clicked. I felt we were on the same wave-length"*. Participants rated the items on a 7-point Likert scale ranging from 1 (not at all true, disagree completely) to 7 (very true, agree completely). See supplementary material for the full scale.

4.3.1.3. *Impression of the robotic object.*
Although it was not our main research question, we also measured the participants' attitudes toward the robot using the 'Godspeed Questionnaire', a 5-item Likert scale measure (Bartneck et al., 2009). This assessment allowed us to test how the robot's behavior influenced its perception (i.e. the HRI effect). The three subscales relevant for this study were 'Animacy', 'Perceived Intelligence' and the 'Robot's Likability'. See supplementary material for the full scale.

4.3.2. *Qualitative dependent measures*
At the end of each session, we conducted a post-experimental interview (based on Henkel et al., 2014; Hoffman, Birnbaum, Vanunu, Sass, & Reis, 2014). The interview was conducted in the experimental room, in the presence of the robotic object, after the conversation ended, and after completing the questionnaires. To gain a deeper understanding of the participants' experience it was critical to conduct an immediate post-experience interview, in the same room where the conversation took place, with the robot present during the interview. These requirements could not be satisfied with both participants. Thus, we performed an ad-hoc random selection, and in half of the sessions asked the participant sitting on the right to join us for the interview, and in the other half asked the participant sitting on the left. The experimenter conducted a 10-minute semi-structured interview with the participant while sitting next to the robot. The specific choice of a semi-structured interview allowed for flexibility during data collection while remaining grounded in a particular framework (Galletta, 2013). The interview provided an opportunity to better understand the participants' thoughts, emotions, and attitudes. The interview included questions concerning the overall experience, the conversation itself, the other participant, and the robotic object. Example questions include: *"What was it like talking to your partner?"; "How would you define the role of the robotic object?"; "How did you feel about the presence of the robotic object in the room?"*. See supplementary material for all interview questions.

4.3.3. *Number of smiles*
Based on Burgoon, Buller, Hale, and de Turck (1984), we also documented the number of smiles (between participants) in each of the three conditions as an implicit non-verbal measure of participants' interpersonal evaluation (Burgoon et al., 1984). The video analysis scoring protocol was strict and included only smiles related to interpersonal evaluation (meaning smiles from one participant to the other). Smiles that were not directed toward the other participant, including smiles toward the robot, were not documented.

4.4. *Procedure*

The main experimental manipulation involved a debate, with the robot as side-participant. A debate context was chosen due to its structured turn-taking nature, which enables a more consistent experience of the robot's responsiveness. Another reason for choosing debate context was to avoid ceiling effects, as debate typically raises a mild conflict between participants (Johnson & Johnson, 1985; Simons, Pelled, & Smith, 1999), leading to a slight decrease in their interpersonal evaluation due to the opposite attitudes they are required to present (Eiser & Eiser, 1986; Heider, 2013).

The experiment was conducted in two separate rooms. It began in a room with two desks and two chairs where participants signed a consent form and were asked to perform an initial short introduction conversation to ensure basic acquaintance level. Next, participants were given a short text on the topic of the debate (prohibition of alcohol sales in their country between 11 pm to 6 am). This topic was chosen as it was age relevant and had the potential to be engaging, without being highly emotional. The experimenter introduced the debate topic and randomly assigned a role for each participant (for or against alcohol sales). Participants were given five minutes to read a text that included relevant information and to prepare their arguments for the debate. Participants were then taken to the experimental room. The reasoning behind separating the location of the opening part from the actual debate was to minimize the exposure to the robot before the conversation began.

In the experimental room, participants were asked to take a seat on one of two office chairs, placed at a precise location with a 'conversation distance' of 76 cm between them (based on Burgoon et al., 1984). The robot was placed on a small table (70 cm in height) exactly between them with a slight offset, to reduce interference with participants' direct communication and eye contact. The robot's height reached a human's shoulder when seated (See Figure 7).

Participants were informed that in the debate each participant speaks only during his/her turn. Each debate consisted of eight, 30-second alternating phases (four phases per participant). In each phase, one participant presented his/her arguments, and a knock on the door was defined as a signal that the 30-second phase was over and that participants should switch roles.

The experimenter presented the robot in the following way: "this is Kip, a robotic object. It will listen to the debate". The robot's presentation was similar across all conditions and participants were not given any description of the robot's behavior (e.g. gazing, attending, breathing). After confirming that the participants understood the instructions, the experimenter left the room. The robots' initial behavior was set as 'Non-responsive' and was identical in all three conditions. The wizard watched the experiment from an observation room, controlling the robot's behavior using the WoZ interface based on a strict protocol for each condition. In the 'Responsive to Speaker' condition, the robot performed a gesture toward the speaker immediately after he/she began presenting the argument. At every phase change, when the speaker's role switched, the robotic object shifted to the designated speaker. In the 'Responsive to Addressee' condition, the robot immediately performed a gesture toward the addressee, shifting to the designated addressee in each phase. In the baseline condition, the robot remained in the 'Non-responsive' behavior throughout the experiment, regardless of participants' role changes. As described in Figure 4, during the responsive conditions the wizard tracked interruptions in the discussion (e.g. when the Addressee interrupts the Speaker) according to a strict protocol. If an interruption event occurred, the wizard activated the 'Responsive to Interrupter' behavior: the robot shifted and briefly gazed at the interrupting participant, and then returned to the previous position, gazing at the Speaker. At the end of the debate conversation, the robot was set to the initial 'Non-responsive' behavior. To overcome variance in the shifts of the

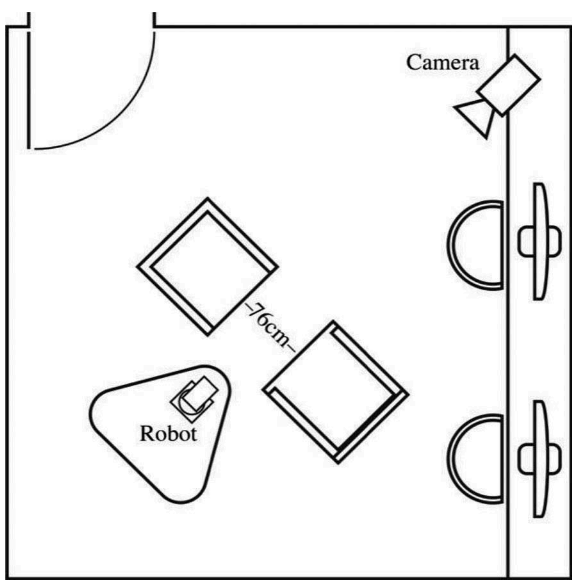


Figure 7. The experimental room setup: the two participants were engaged in a debate conversation; the robotic object was placed on a small table exactly between them with a slight offset to avoid interference.

robot's responses (due to the human operator response time) a few measures were taken. First each robotic behavior was activated by a single button press, reducing the requirements from the wizard to a minimal response. Second, the robot response shift was performed immediately after participants received a signal switch turn. This left the operators with a high level of control over the robot's behavior timing; thus, the operator was not required to monitor the response to the participants behavior. Third, this protocol was intensively practiced by the wizard prior to running the experiments, until a minimal delay was reached.

Following the conversation, the experimenter reentered the room and asked each participant to complete the questionnaires on a laptop computer. One randomly-selected participant was thanked for their participation and left the room, and the other stayed for a short semi-structured qualitative interview. During the interview, the robot remained in the 'Non-responsive' behavior. In addition, the interviewer never used any gendered pronouns when describing the robot (e.g. He, She, or It), and used the term 'Robotic Object' when referring to the robot. At the end of the interview, the participant was asked how he/she thought the robotic object was operated, verifying that they assumed it was behaving autonomously and did not suspect it was operated remotely using a WoZ technique. As customary in qualitative data gathering, immediately following the interview the researcher took notes regarding her observations and thoughts, as an aid to the theme analysis process (Galletta, 2013). The experiment was documented by a video camera.

A few weeks after the experiment, a second post-study interview was conducted with 10 participants (5 participants from each responsive condition). Participants were presented with the study results and were asked to share their ideas for future applications of the robot.

5. Findings

Mixed methods including both a quantitative and qualitative analysis were applied to the data. For the quantitative analysis, we performed a one-way ANOVA comparing the three conditions for the following dependent quantitative measures: 'Relational Communicational Scale' (5 subscales); 'Human-Human Liking Scale'; 'Godspeed Questionnaire' (3 subscales); and 'Number of smiles'.[1] For the qualitative analysis, we used the thematic coding method (Gibbs, 2008) to identify repeating themes in the interviews conducted at the end of the experiment. This thematic analysis was also applied to the second post-study interview that was conducted a few weeks after the experiment. Notably, most of the dependent measures are subjective self-report measures apart from the number of smiles which is an objective non-self-report measure based on the participants' implicit non-verbal behavior.

5.1. *Quantitative data*

5.1.1. *Relational communicational scale*

A separate one-way ANOVA analysis was performed for each of the five subscales of the 'Relational Communicational Scale' (Similarity, Social Orientation, Non-immediacy, Intimacy, and Arousal; See Figure 9). The behavior of the robotic object in the different conditions had a significant effect on each of the 'Relational Communicational' subscales (See Figure 8).

Post-hoc multiple comparisons using Scheffe's method indicated that the 'Responsive to Speaker' and 'Responsive to Addressee' conditions resulted in significantly higher ratings when compared to the

[1]All analyses were also run with gender as additional independent variable and level of acquaintance as covariate. As their interaction with the robot's conditions and main effects were not significant, we do not report them in the paper (see Supplementary Data for the analysis). We note that gender and the level of acquaintance conditions should be further examined with a balanced sample size of all independent variables. These interactions are beyond the scope of this paper. In addition, we correlated the level of acquaintance with the dependent variables related to the HHI. None of the correlations were found significant (see Supplementary Data for the analysis). We also performed all analyses using a non-parametric test, as there is some disagreement in the scientific community regarding the accuracy of conducting a parametric analysis on the ratings of a Likert scale, even when using a 5 levels scale (see Supplementary Data for the analysis).

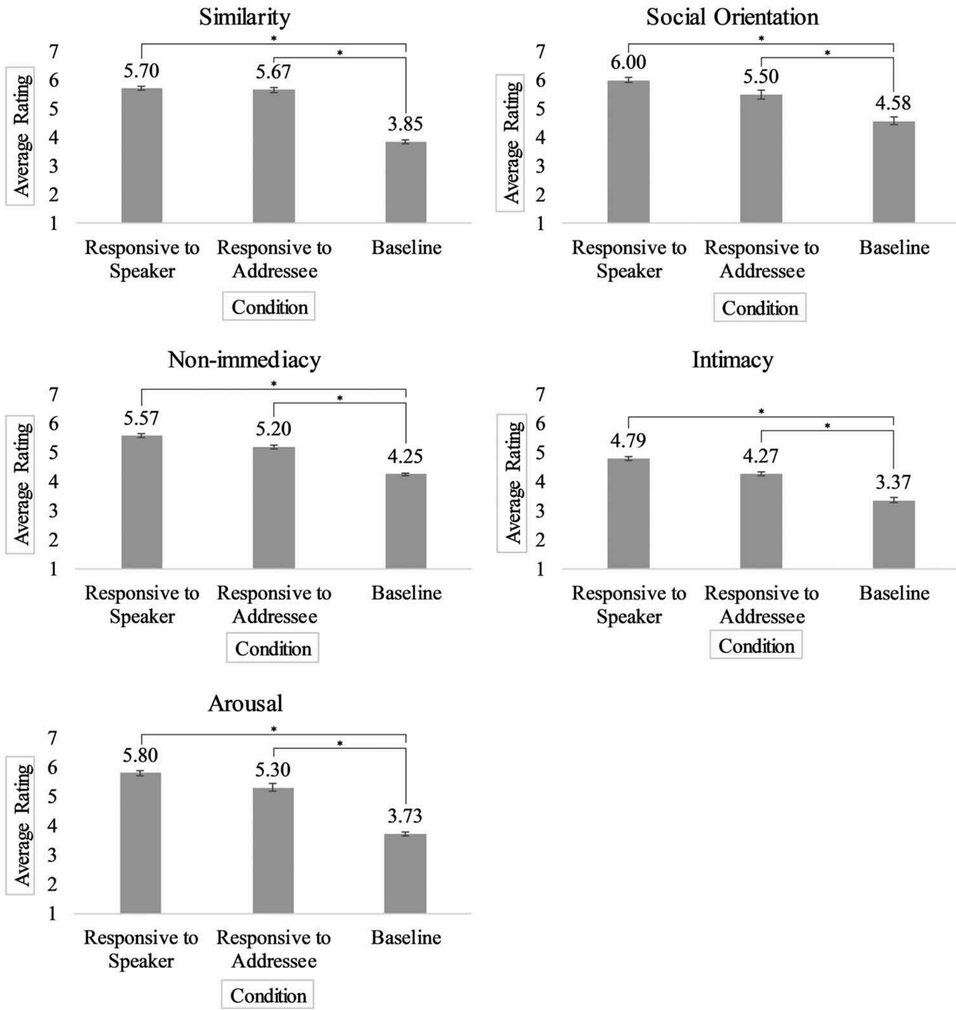


Figure 8. Relational communicational scale, 5 subscales analysis presenting the difference between the 3 conditions: 'Responsive to Speaker', 'Responsive to Addressee', 'Non-responsive' (baseline condition).

baseline condition. The difference between 'Responsive to Speaker' and 'Responsive to Addressee' was not significant (See Figure 9). This pattern was evident across all subscales. In other words, in the robot's responsive conditions, participants rated their partner as higher in similarity, social orientation, non-immediacy, intimacy, and arousal, in comparison to the baseline condition.

5.1.2. *Human-human liking scale*

A similar pattern was found for the 'Human-Human Liking Scale' measure. The robot's behavior had a significant effect on the conversation-partner Liking ratings, F(2,57) = 34.06, p < .0005, *partial* $\eta^2 = 0.54$(See Figure 10). Post-hoc multiple comparisons using Scheffe's method indicated that 'Responsive to Speaker' (p < .0005) and 'Responsive to Addressee' (p < .0005) conditions resulted in higher conversation-partner Liking ratings than the baseline condition. The difference between the 'Responsive to Speaker' and the 'Responsive to Addressee' conditions was not significant. In other words, the robot's responsive conditions led participants to rate their conversation-partner as more likable.

	ANOVA	Scheffe post-hoc analysis: 'Responsive to Speaker' vs. Baseline	Scheffe post-hoc analysis: 'Responsive to Addressee' vs. Baseline	Scheffe post-hoc analysis: 'Responsive to Speaker' vs. 'Responsive to Addressee'
Similarity	F(2,57) = 48.56, p < 0.0005 $eta^2 = 0.63$	p < 0.0005	p < 0.0005	F < 1
Social Orientation	F(2,57) = 8.26, p < 0.0005 $eta^2 = 0.23$	p = 0.001	p = 0.04	F < 1
Non-immediacy	F(2,57) = 27.43, p < 0.0005 $eta^2 = 0.49$	p < 0.0005	p < 0.0005	F < 1
Intimacy	F(2,57) = 26.65, p < 0.0005 $eta^2 = 0.48$	p < 0.0005	p < 0.0005	F < 1
Arousal	F(2,57) = 27.77, p < 0.0005 $eta^2 = 0.49$	p < 0.0005	p < 0.0005	F < 1

Figure 9. Relational communicational scale – ANOVA and Scheffe analysis summary of the 5 subscales.

5.1.3. *Godspeed questionnaire*

A separate one-way ANOVA analysis was performed for each of the three subscales of the 'Godspeed Questionnaire' (Animacy, Perceived Intelligence, and Robot Likability). The different conditions had a significant effect on each of the Godspeed Questionnaire subscales.

5.1.3.1. ***Animacy.*** The robot's behavior had a significant influence on the Animacy ratings, $F(2,57) = 30.15$, $p < .0005$, *partial* $\eta^2 = 0.51$. Post-hoc multiple comparisons using Scheffe's method indicated that both 'Responsive to Speaker' ($p < .0005$) and 'Responsive to Addressee' ($p < .0005$) conditions resulted in higher Animacy ratings than the baseline condition. The difference in Animacy ratings between the 'Responsive to Speaker' and the 'Responsive to Addressee' conditions was not significant (See Figure 11).

5.1.3.2. ***Perceived intelligence.*** The robot's behavior had a significant influence on the Perceived Intelligence ratings, $F(2,57) = 11.31$, $p < .0005$, *partial* $\eta^2 = 0.28$. Post-hoc multiple comparisons

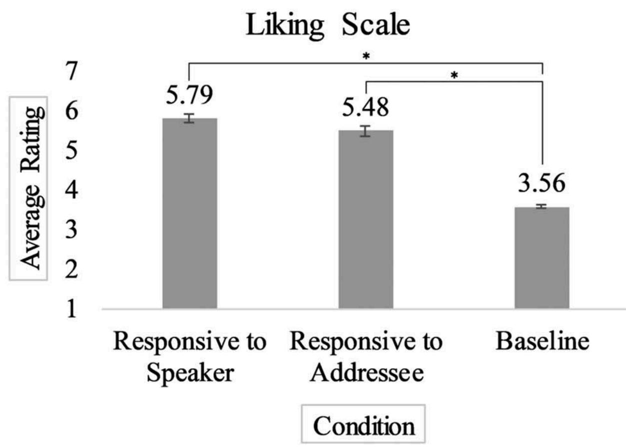


Figure 10. Human-human liking scale analysis presenting the difference between the 3 conditions: 'Responsive to Speaker', 'Responsive to Addressee, 'Non-responsive' (baseline condition).

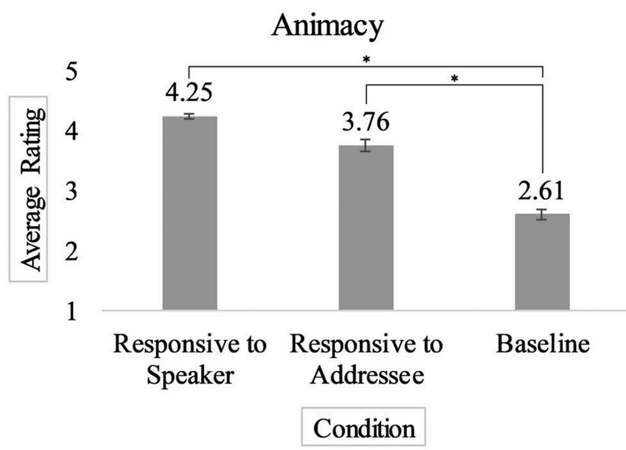


Figure 11. Animacy analysis presenting the difference between the 3 conditions: 'Responsive to Speaker', 'Responsive to Addressee', and 'Non-responsive' (baseline condition).

using Scheffe's method indicated that 'Responsive to Speaker' resulted in higher Perceived Intelligence ratings than the baseline condition (p < .0005). All other effects were not significant (See Figure 12).

5.1.3.3. ***Robot's likability.*** The robot's behavior had a significant influence on the Likability ratings, F(2,57) = 15.51, p < .0005, $partial\eta^2 = 0.35$. Post-hoc multiple comparisons using Scheffe's method indicated that both 'Responsive to Speaker' (p < .0005) and 'Responsive to Addressee' (p = .006) conditions resulted in higher Likability ratings than the baseline condition. The difference in Likability ratings between the 'Responsive to Speaker' and the 'Responsive to Addressee' conditions was not significant (See Figure 13).

5.1.4. *Number of smiles (non-verbal measure)*

The video footage from all sessions was analyzed to identify smile events and measure their frequency. Two independent raters performed the analysis, identifying events where participants smiled toward the other participant as a "smile event". Smiles toward the robot were not documented. Inter-rater reliability was checked and found to be high (Kappa = 93%). The frequency of the

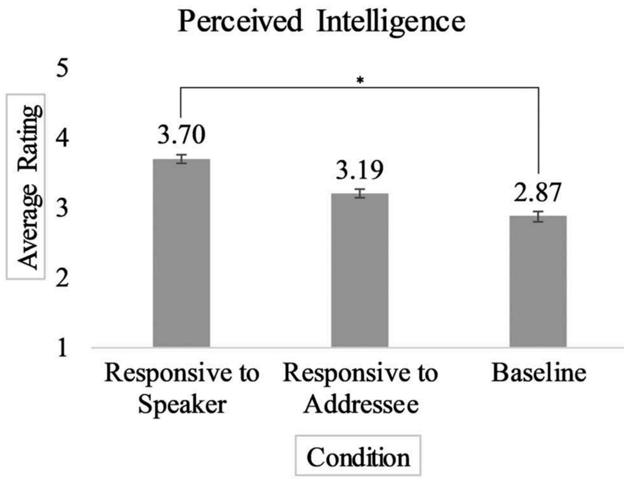


Figure 12. Perceived intelligence analysis presenting the difference between the 3 conditions: 'Responsive to Speaker', 'Responsive to Addressee', and 'Non-responsive' (baseline condition).

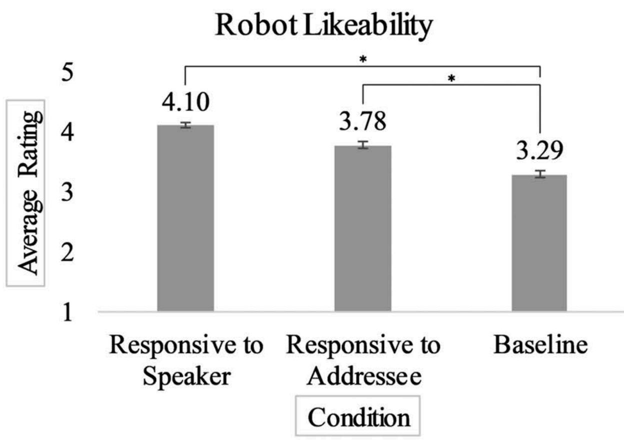


Figure 13. Robot's likability analysis presenting the difference between the 3 conditions: 'Responsive to Speaker', 'Responsive to Addressee', and 'Non-responsive' (baseline condition).

number of smiles was documented per condition. Results indicated a significant effect of the robotic object's behavior on the number of smiles, $F(2,57) = 143.56$, $p < .0005$ (See Figure 14). Post-hoc multiple comparisons using Scheffe's method indicated more smiles in the 'Responsive to Speaker' condition ($p < .0005$) in comparison to the 'Responsive to Addressee' condition ($p < .0005$) and the baseline condition ($p < .0005$). No significant difference was found between the 'Responsive to Addressee' and the baseline condition. In other words, "Responsive to Speaker" condition, in which leaning and gaze gestures are directed toward the speaker, led to a higher number of smiles than the other two conditions.

5.2. *Qualitative data*

5.2.1. *Qualitative analysis process*

The interviews conducted at the end of the study were transcribed and analyzed using Thematic Analysis (Boyatzis, 1998), a qualitative analysis methodology commonly used in HCI and HRI. The

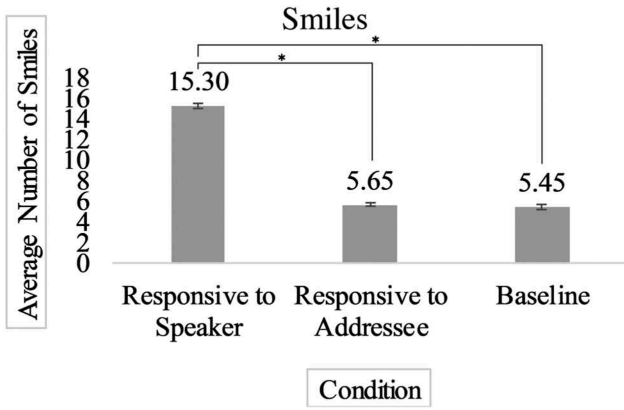


Figure 14. The difference in number of smiles between the 'Responsive to Speaker' condition and the two other conditions: 'Responsive to Addressee' and 'Non-responsive' (baseline condition).

thematic analysis process is done by several researchers on qualitative data such as semi-structured interviews. Two researchers analyze and rate the data, identify repeating themes, comparing and contrasting their initial findings, until meaningful insights are generated. Our analysis included four stages: (1) a primary rater reviews all transcripts, performs initial coding, and identifies initial themes; (2) the initial themes are discussed with a second rater; inconsistencies are discussed until resolved, and a list of mutually-agreed themes is defined; (3) following theme definition, both raters analyze a selection of the data independently, inter-rater reliability was checked and found to be high (Kappa = 89%); (4) following inter-rater reliability validation, the two raters analyze the rest of the data. The interviews included all perspectives from the three conditions, thus satisfying the requirement for saturation (Morse, 1995).

5.2.2. *Qualitative-based themes*

The qualitative analysis process led to the following four themes: "Robotic Object as a Listening Partner"; "Robotic Object as a Conversation Supervisor"; "Robotic Object as a Listening Machine"; and "Robotic Object Unnoticed". We note that the word "it" is not a common way to relate to objects in participants' native language. This may explain why in the interview participants used the words "Kip", "he", or "the robot" when relating to the robotic object.

5.2.2.1. ***Theme 1: 'Listening Partner'.*** Reactions that belong to this theme relate to the robotic object as an active listener, an attentive and interested entity. This theme was suggested by all participants in the 'Responsive to Speaker' condition (20/20), no participants in the 'Responsive to Addressee' condition (0/20), and no participants in the baseline condition (0/20), (See Figure 15).

Selected quotes from participants in the 'Responsive to Speaker' condition include:

> Kip was amazing. He listened and noticed me, as if there was another person in the room. (P19).

> If she [the other participant] didn't listen to me, Kip did. (P21).

> Kip's gestures made me feel that he was interested in what I was saying. Even when Kip was moving towards her [when the other participant spoke, the robot shifted to her as she became the Speaker], it made me feel also more interested in what she had to say. Kip was attentive, a good and supportive listener. (P60).

> Kip was interested in me. I looked forward to my turn so that Kip would face me. (P21).

When asked about the robotic object's role, participants presented logical explanations for Kip's role in the discussion, defining it as a side participant:

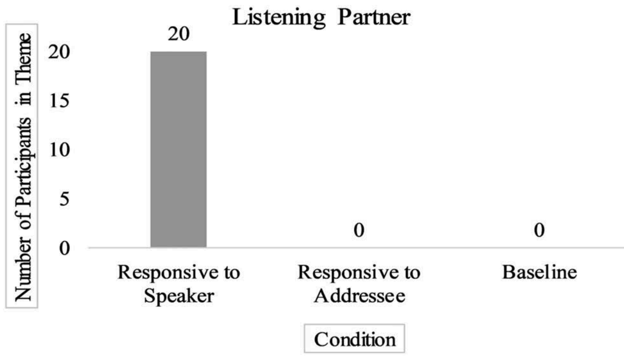


Figure 15. The distribution among the different conditions with regards to reactions that belong to the 'Listening Partner' theme.

> He acts as an audience, even though he isn't at an intelligence level appropriate for the conversation, he listens. It feels as if he is alive and active, but I didn't expect him to take an active part in the conversation. (P21).

> I didn't feel that he could think, but I felt that he respected me. He listened, looked at me and was attentive. (P11).

Participants who were not acquainted with each other prior to the debate indicated that the robotic object made the interaction more comfortable:

> It feels as if he breaks the ice, especially since we don't know each other. (P30).

> His presence did affect me – he gave structure to the conversation. It helped that there was someone else around, it was less awkward. (P52).

Participants also indicated that the robotic object didn't interfere with the conversation:

> Kip didn't interrupt at all. When I got into the conversation, I felt him, but he wasn't in the center of my attention. (P19).

> Kip gently guides the conversation. (P4).

> His presence felt good, I noticed him, but he didn't cut the flow of the conversation. (P39).

5.2.2.2. Theme 2: 'Conversation Supervisor'. Reactions that belong to this theme relate to the robotic object as an entity responsible for keeping the addressee engaged in the conversation, and "monitoring" his/her behavior. This theme was suggested by 0/20 participants in the 'Responsive to Speaker' condition, 11/20 participants in the 'Responsive to Addressee' condition, and 0/20 participants in the baseline condition (See Figure 16).

Selected quotes include:

> He didn't care about what I had to say, but about what the listener was feeling and thinking. (P22).

> He demands the listener's attention. (P37)

> At first it felt as if he was acting this way by mistake since it felt rude that he wasn't facing me while I was speaking … and then I felt that he was testing out the interaction between us, it seemed that the person listening was also important to him. (P55).

This role is related to a less conventional behavior in human-human conversation, and its influence is in line with previous studies indicating that conversation regulation is perceived as a valid role for a robot (Hoffman et al., 2015).

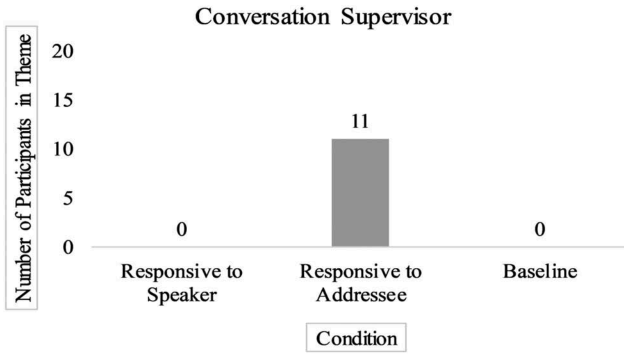


Figure 16. Participants' distribution among the different conditions with regard to the 'Conversation Supervisor' theme.

5.2.2.3. *Theme 3: 'Listening Machine'.* Reactions that belong to this theme relate to the robotic object as a machine-like entity or just an object in the room. This theme was suggested by 0/20 participants in the 'Responsive to Speaker' condition, 7/20 participants in the 'Responsive to Addressee' condition, and 20/20 in the baseline condition (See Figure 17).

Selected quotes from participants in the baseline condition include:

> He was just present there, I didn't perceive it as human-like. It was just an object. (P26).

> I saw the robot as just any other object in the room. (P13).

> The robot wasn't dominant at all, it was like any other item". "It's just an object. Can't do anything. (P32).

> It's like Kip wasn't here in the room at all. (P47).

> I expected it to wake up and rise a little, but it didn't. (P13)

When asked about the robotic object's role, participants didn't associate it with a certain role or purpose during the conversation. However, they did perceive it as a listener:

> Its purpose in one sentence: an object that listens and breathes to itself. (P13).

> Wasn't dominant at all during the debate, his role was to listen from the outside. (P8).

The seven participants in the 'Responsive to Addressee' condition that were associated with this theme did not perceive the robot as a side participant in the conversation, and were perplexed by its lack of purpose, attributing its focus on the addressee to an error:

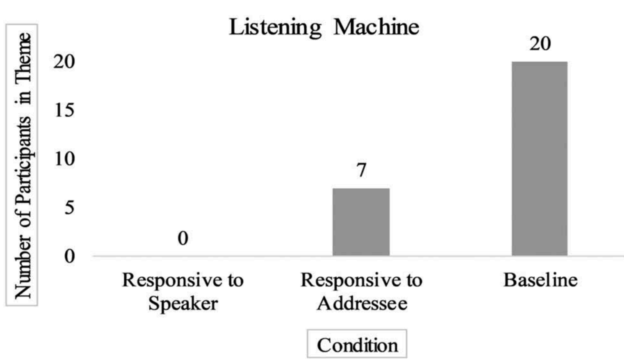


Figure 17. Participants distribution among the different conditions with regards to the 'Listening Machine' theme.

> I am sure there was a bug, he listened to the one that was not speaking, I didn't understand why. (P32).

> Maybe his role was to test our confidence in the way we speak. I noticed that he was facing the listener – something about that felt like an error, it was fake and unreliable since it wasn't clear what its purpose was. (P41).

5.2.2.4. *Theme 4: 'Unnoticed'.*

Two participants didn't notice the robotic object at all. They explained their lack of attention to the robot by the stress and cognitive load related to the debate. This theme was suggested by 0/20 participants in the 'Responsive to Speaker' condition, 2/20 participants in the 'Responsive to Addressee' condition, and 0/20 participants in the baseline condition. Selected quotes include:

> I think I was a little nervous and unfocused, that's why I put all of my attention into my claims for the debate and I didn't notice Kip at all. (P2).

> I was so focused on the debate that Kip was like air to me … I was focused on what I had to say and not on anything else. (P8).

5.3. *Possible applications: post-study interview analysis*

All interviews were transcribed and analyzed. Participants were asked to share possible real-life situations in which a robotic object like the one they experienced in the study can take a meaningful role.

5.3.1. *Suggestions from participants in the 'Responsive to Speaker' condition*

Two participants suggested a dating context:

> I think he should be used in the dating scene. This could create a lighter atmosphere, especially on a first date that can be a bit awkward. (P1).

> Kip can accompany dates. I can imagine a number of Kips scattered around romantic restaurants. It could create a really pleasant atmosphere. (P19).

Three participants suggested a conflict resolution or negotiation context:

> The first thing that came to my mind was therapy – perhaps mediation between couples or settling disputes. In such cases Kip could create a pleasant and friendly atmosphere, and because he is not a person it may give a more neutral effect than another person in the room. Kip could try to make both sides feel more committed to being tolerant and pleasant to each other. (P24).

> Putting Kip in court where the atmosphere might be unpleasant. Kip may help by being equally sensitive to all sides – that's one of the things I loved about him – when I talked, he looked at me and when she spoke, he was looking at her, he was equally interested in us regardless of what we said. This can make the sides feel more comfortable talking and opening up in an honest manner since Kip is with them like a tolerant friend. (P21).

> I could see Kip helping when people are trying to sign contracts and close a deal, Kip can temper the spirits and help reach a fair compromise from both sides. (P19).

Two participants proposed educational context:

> My mother is a teacher and she has to deal with incidents between students, even in the middle of class … so maybe Kip can try to make students more sensitive and sympathetic towards each other. (P4).

> In after-school activities, where I work these days, I come across many cases where it is very difficult for instructors to capture children's attention. Maybe if Kip could act just like a member of the group, and would look at the instructor when she speaks, it will lead to a higher level of attention. The children will feel more committed to behave. (P21).

5.3.2. *Suggestions from participants in the 'Responsive to Addressee' condition*

Two participants suggested conflict resolution context:

> Perhaps it can be integrated into contexts that require a relaxed atmosphere in order to achieve results. Maybe people will feel less comfortable talking in unpleasant ways in front of Kip. (P15).

> I do a lot of babysitting. When there are small brothers of similar ages, they often fight over toys. Maybe a robot like Kip can teach children the importance of listening to others. (P18).

Two participants suggested educational contexts:

> Maybe in class Kip can turn his gaze and move between the students. This can make them feel a stronger commitment to stay focused and listen to the teacher. (P18).

> Let's say in a private lesson that the teacher talks, and Kip looks at the student … it can be interpreted by the student as if kip is making sure that he is attentive. (P22).

Three participants suggested an "engagement supervisor" in gatherings:

> Having Kip as a supervisor in a lecture … when students are distracted by their computer or their smartphone maybe a few Kips in the room will make them feel more committed to the class. (P20).

> When the entire family meets, there are almost always a few who are not 100% with us because they are on their smartphones. Maybe Kip would glance at them to encourage them to get off their phones. (P22).

> At a social meeting with a lot of people. I imagine there will be robots who will keep the atmosphere pleasant and make sure everyone in the conversation is more connected and synchronized. (P25).

6. Discussion

In this work, we showed that leaning and gaze gestures of a responsive robotic object significantly influenced Human-Human Interaction (HHI). The responsive robotic object improved participants' interpersonal evaluation when engaged in a conversation. Compared to the baseline condition, the two responsive conditions (i.e. 'Responsive to Speaker' and 'Responsive to Addressee') led to higher ratings of the human conversation-partner. This finding extends previous work by showing that a responsive robotic object can influence people's direct perception of each other and the quality of the interaction between them. Previous work that integrated a robot in HHI showed an influence on people's perception of the robot (Sidner et al., 2005; Takayama, Dooley, & Ju, 2011; Takayama & Pantofaru, 2009), and on indirect HHI factors such as group performance and collaboration patterns (Forlizzi, 2007; Shah et al., 2011; Tennent et al., 2019). In this study, we show that the robotic object's responsive gestures contributed to participants' positive direct interpersonal evaluation. This positive effect was evident even though the robotic object was presented as a mere side-participant to the conversation, without declaring that the robot's purpose is to influence the human-human interaction. As such, there was no direct interaction between the robot and the humans.

More broadly, but still within the context of a face-to-face conversation, our findings reveal that minimal gestures designed as responsive social cues can influence human-human interaction even when performed by a non-humanoid robot. Non-humanoid robots are becoming more popular in industry and academia, and in most cases, they leverage simple physical gestures as a primary communication modality. This study focused on testing a basic research question concerning the effect of these simple physical gestures, and specifically the effect of minimal responsive gestures on human-human interaction, independently of other factors such as appearance or voice communication. Our findings indeed show that even minimal responsive gestures can influence HHI and can inform robot developers in regard to the attention that should be given to movement design. Our work leaves many future research questions unanswered and sets the ground for additional studies with the context of robot influence on HHI.

As the robotic object does not directly mimic human social cues, the strong influence of the two responsive conditions on the HHI quantitative measures may be attributed to participants' interpretation of the robot's responsiveness as communicating attention (Clark, 2005). When the robotic object was responsive (to Speaker or Addressee), most participants intuitively accepted it as a side-participant and treated it as a third party attentive to the conversation. This association to attention is further supported by the variance found in participants' interpretations: when the behavior of the robotic object was in-line with common attentive human behavior in a conversation ('Responsive to Speaker') there was no variance in participants' interpretations for the robot as a listening partner. However, when the robotic objects' behavior was not in-line with common human attentive behavior in conversation ('Responsive to Addressee'), there was greater variance in participants' interpretations. This idea is further supported by the ratings of the robot's perceived intelligence, that were higher only when the robot was responsive toward the speaker. When the robot's behavior was consistent with the common norms for side-participants in a conversation, it was perceived as more intelligent by most of the participants.

Further analysis of the two responsive conditions revealed a difference in the robot's influence on participants' nonverbal behavior. Analysis of participants' smiles toward each other indicated that the number of smiles was significantly higher in the 'Responsive to Speaker' condition, compared to both the 'Responsive to Addressee' and the Baseline conditions. This effect can be explained by the known positive influence of both human gaze & leaning gestures in HHI (Breed, 1972; Bull, 2016). The qualitative analysis shed additional light on the difference between the two responsive conditions. All participants in the 'Responsive to Speaker' condition used a positive description for the robotic object's role, as manifested in the "Listening Partner" theme. In contrast, most participants in the 'Responsive to Addressee' condition described its role as a "Conversation Supervisor", that monitors the conversation (a less positive description). This can further explain the finding indicating fewer smiles in that condition.

Another interesting pattern observed in the findings is the consistency in participants' interpretation of the robotic object's conversation capabilities. Participants accepted its role as a side-participant, and none of the participants expected the robotic object to perform a different role. Participants directly stated that they did not expect the robotic object to take an equal part in the conversation and were not disappointed that its participation in the conversation was non-verbal: *"I didn't expect Kip to be as involved as her [the other participant], after all, the robot is not a person, but I still feel that its interactivity contributed to our conversation"*. This finding is relevant to one of the challenges in acceptance of humanoid robots, where users develop unrealistic expectations about the robot and become frustrated when the robot does not fulfill these expectations (Wu, Fassert, & Rigaud, 2012). It is possible that the robot's non-humanoid design addressed this challenge by preventing false expectations. This initial finding should be further studied.

From a technical perspective, any WoZ-controlled study raises questions as to the possible implementation of similar robot behaviors in real situations with autonomous robots which leverage sensing instead of human control. In our study, the human activating the WoZ controller had clear guidelines regarding timing for triggering a gesture, which was dependent only on speaker onset, a relatively easy signal to detect. In addition, due to human perception, attention, and reaction time limitations, the reaction time of the human WoZ controller was not completely consistent. Still, we found the effect of the robot's behavior on study participants to be evident in the majority of the responsive condition trials. Perhaps minor differences in response time are not noticeable by participants and do not eliminate the influence on human behavior. Further studies should validate this assumption. For an autonomous version of the robot behavior used in this study, we can suggest that the benchmark for autonomous systems reaction time be similar to human reaction time, including the slight variations found in human reaction time.

In sum, our findings contribute to the emerging research field of HHRI, showing that a responsive robotic object can influence participants' interpersonal evaluation and the quality of the interaction between them. Specifically, robotic objects, despite having limited communication modalities, have a great potential to influence HHI and some participants directly pointed their advantages including raising appropriate expectations (*"He acts as an audience … but I didn't expect him to take an active part in the conversation", P21*) and the fact that they do not distract the conversation (*"Kip didn't interrupt at all, when I got in the conversation I felt him, but he wasn't in the center of my attention", P19*; *"His presence felt good, I noticed him, but he didn't cut the flow of the conversation", P39*). However, with the great potential to enhance human-human interaction also comes a risk. While robotic objects can be used in a range of meaningful roles, their indirect influence may also be misused, for example, to direct participants' attention toward specific participants while avoiding others, or by influencing conversants dynamics during face-to-face conversations. An ethical agenda should be developed for this emerging field, and more research is required in order to further explore and validate the range of influences robotic objects may have in HHI context.

7. Limitations & future work

This study has several limitations. Regarding the qualitative methodology, the data obtained in the interviews may be subjected to bias by the interviewer, which could unknowingly influence interviewees' responses (Opdenakker, 2006). To limit these effects, we followed a strict interview protocol, raised the interviewer awareness of this effect, and made sure the interviewer maintained neutral language during the interviews. In addition, interviews may have been affected by the "good subject effect" (Nichols & Maner, 2008), in which the participant wants to provide pleasing responses to the interviewer. To limit this effect, the interviewer encouraged participants to be open and express their true opinions while reassuring them that anything said is helpful and valuable to the research. The findings indeed show variance in participants' responses, including association of both positive and negative roles with the robot's behavior. Apart from the interview, the questionnaires are also subjective self-report measures that can be influenced by the participants' beliefs regarding the aim of the study and the expectations from them. We therefore suggest that future work could benefit from additional implicit objective measures. This type of measure (including reaction times, number of uses, etc.) can provide additional support for the findings in the current study.

The WoZ methodology has known limitations, mostly since it depends on a human operator that activates the robot's gestures. Most notably, human responses will have unavoidable variances in response time due to perception, attention, and motor characteristics of the operators. We took measures to minimize the variance of the human operator through the design of a simple and reactive WoZ interface as well as through operator practice (see: Method section) but clearly some variance is unavoidable and may have some implicit impact on participants' experience. The same limitation, of slight inevitable variances in response time, is also to be expected in autonomous systems that analyze human behavior in real-time in a noisy environment, express through robotic mechanisms and induce delays in network protocols.

Regarding the conversation context, while we present an effect of a responsive robotic object on the evaluation of HHI, our findings are limited to the specific conversation context tested (a debate in our case). We chose debate as a specific type of conversation setting in order to maximize the control over the robotic object's gestures in the context of the conversation. The structured debate context is a specific case of conversation and the robotic object's influence should be further tested in less-structured social interactions. In addition, human-human interactions take many forms, including more complex group settings with different relations between the group members. Finally, the topic of conversation may also influence the robotic object's effect on the HHI, it is possible that a more or less controversial topic would lead to different results.

We also note that the effect of the robot's responsiveness should be further tested in a long-term interaction study. It is possible that over time habituation will reduce the effect of the robot's minimal gestures. Several strategies can help cope with habituation and should be tested, for example a wider range of minimal gestures with different variations selected over time (while communicating the same non-verbal message), or slight variation in movement characteristics such as acceleration, speed, or start/end points. A theoretical foundation for these suggested strategies is that leaning and gaze are basic social cues in HHI that indicate peoples' attitudes and level of agreement (Breed, 1972; Bull, 2016), and are constantly used by people on a daily basis. It is possible, therefore, that subtle variations in the robot's gestures will be sufficient in preventing or reducing habituation effects. This assumption should be tested in future work.

Another direction that should be further investigated is the influence of minimal movement on human-human interaction across different types of agents (e.g. virtual agents and voice interfaces). In this work we focused on a physical robotic object as a side participant to human-human interaction. Previous studies have indicated that voice agents or light/screen cues can also be integrated into a conversation (Cuijpers & Van den Goor, 2017; Hoffman et al., 2015; Iio, Yoshikawa, & Ishiguro, 2017; Nagao & Takeuchi, 1994). Robots were shown to have advantages compared to voice agents as they lead to fewer interruptions (Luria et al., 2017), and emotions were better understood in face-to-face interactions with a robot compared to interactions with a virtual agent or an on-screen robot (Bretan, Hoffman, & Weinberg, 2015). Future work should further assess if these advantages are also evident in the context of human-human-robot interaction. Apart from the agent's type, several other factors may interact with the robot's influence on HHI, including the communication modality (movement, audio, verbal, lights, etc.), the robot's role (side participant, addressee, overhearer), the robot's behavior (random behavior vs. conversation relevant behavior), the compatibility between the robot's gestures and the robot's appearance, and the robot's design (humanoid, object, creature). Whereas the current study focused on the effect of minimal robotic movement on HHI, future work should extend the current contribution with studies on the above-mentioned research questions and relevant baselines. The interaction with factors related to participants' personality and gender should also be further explored. Specifically, interactions between the robot's conditions and level of acquaintance, gender and the effect of mixed gender vs. single gender pairs, personality traits, and familiarity with technology.

8. Conclusion

We presented a study testing the effect of a robotic object's responsiveness on people's interpersonal evaluation in face-to-face conversation context. Our results indicate that a responsive robotic object, performing minimal movement of "gaze" and "leaning" gestures, has a significant effect on HHI, and can improve the quality of the interaction between the conversation partners. Our work has implications for the HCI community. Researchers, designers, and practitioners in the fields of Human-Robot Interaction (HRI) and Tangible and Embedded Interaction (TEI) can leverage our findings by considering the potential of non-humanoid robots in HHI, and by designing and implementing responsive gestures for such non-humanoid robots. We showed that even minimal movement, with a simple mechanical design of two DoF, is sufficient to influence HHI, and is successfully accepted as a side-participant in human-human conversation. This opens up the opportunity for HRI designers to extend their designs into the non-humanoid domain, and for TEI designers to extend their interactive objects into the robotic domain. For the HCI research community at large, our findings show the need to further study the effect of "minimal responsive movement" in a wide range of human-human interaction use cases.

Acknowledgments

We would like to thank Iddo Wald and Andrey Grishko, for their great contribution to the project.

Funding

This research was supported by the Israel Ministry of Science, Technology and Space (Grant #54178).

HCI Editorial Record

First received on 08 Feb 2019. Revisions received on 19 Jan 2020. Accepted by <Bilge Mutlu>. Final manuscript received on 20 Jan 2020. – Editor

Notes on contributors

Danielle Rifinski (danielle.rifinski@milab.idc.ac.il) is an HRI researcher with an interest in Human-Robot Interaction, and specifically the field of Human-Human-Robot Interaction; She has a BA in Interactive Communications, and is a research assistant at the Media Innovation Lab, School of Communications, IDC Herzliya.

Hadas Erel, PhD (hadas.erel@milab.idc.ac.il) is an HCI researcher and a cognitive psychologist with an interest in social interaction with non-humanoid robots; She is a senior research scientist at the Media Innovation Lab, School of Communications, IDC Herzliya.

Adi Feiner (adi.feiner@milab.idc.ac.il) has a BSc in Computer Science and a special interest in Human-Robot Interaction; She is a research assistant at the Media Innovation Lab, School of Communications, IDC Herzliya.

Guy Hoffman, PhD (hoffman@cornell.edu, http://hrc2.io) is a researcher in Human-Robot Interaction focusing on Human-Robot Collaboration and Social Robot Design. He is an Assistant Professor and the Mills Family Faculty Fellow in the Sibley School of Mechanical and Aerospace Engineering at Cornell University.

Oren Zuckerman, PhD (orenz@idc.ac.il) is an HCI researcher focusing on Tangible Interfaces and Non-humanoid social robots; He is an assistant professor at the School of Communications, and director of the Media Innovation Lab (miLAB), IDC Herzliya.

ORCID

Guy Hoffman http://orcid.org/0000-0002-0404-6159

References

Bartneck, C., & Forlizzi, J. (2004). *A design-centred framework for social human-robot interaction*. RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication, Kurashiki, Japan. (IEEE Catalog No. 04TH8759) (pp. 591–594). IEEE.

Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics*, *1*, 71–81. doi:10.1007/s12369-008-0001-3

Beck, A., Cañamero, L., & Bard, K. A. (2010). *Towards an affect space for robots to display emotional body language*. 19th International symposium in Robot and Human Interactive Communication (pp. 464–469). IEEE, Viareggio, Italy.

Bethel, C. L., & Murphy, R. R. (2010). *Emotive non-anthropomorphic robots perceived as more calming, friendly, and attentive for victim management*. 2010 AAAI Fall Symposium Series, Arlington, Virginia.

Bohus, D., & Horvitz, E. (2014). *Managing human-robot engagement with forecasts and … um … hesitations*. Proceedings of the 16th international conference on Multimodal Interaction (pp. 2–9), Istanbul, Turkey. ACM.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage, Thousand Oaks, California.

Breed, G. (1972). The effect of intimacy: Reciprocity or retreat? *British Journal of Social and Clinical Psychology*, *11*, 135–142. doi:10.1111/bjc.1972.11.issue-2

Bretan, M., Hoffman, G., & Weinberg, G. (2015). Emotionally expressive dynamic physical behaviors in robots. *International Journal of Human-Computer Studies*, *78*, 1–16. doi:10.1016/j.ijhcs.2015.01.006

Bull, P. E. (2016). *Posture & gesture* (Vol. 16). Elsevier, Amsterdam, Netherlands.

Burgoon, J. K., Buller, D. B., Hale, J. L., & de Turck, M. A. (1984). Relational messages associated with nonverbal behaviors. *Human Communication Research*, *10*, 351–378. doi:10.1111/hcre.1984.10.issue-3

Burgoon, J. K., & Hale, J. L. (1987). Validation and measurement of the fundamental themes of relational communication. *Communications Monographs*, *54*, 19–41. doi:10.1080/03637758709390214

Burgoon, J. K., & Koper, R. J. (1984). Nonverbal and relational communication associated with reticence. *Human Communication Research*, *10*, 601–626. doi:10.1111/hcre.1984.10.issue-4

Clark, H. H. (1996). *Using language*. Cambridge university press, Cambridge, England.

Clark, H. H. (2005). Coordinating with each other in a material world. *Discourse Studies*, *7*, 507–525. doi:10.1177/1461445605054404
Correia, F., Mascarenhas, S., Prada, R., Melo, F. S., & Paiva, A. (2018). *Group-based emotions in teams of humans and robots*. Proceedings of the 2018 ACM/IEEE international conference on Human-Robot Interaction, Chicago, Illinois (pp. 261–269). ACM.
Cuijpers, R. H., & Van den Goor, V. J. P. (2017). Turn-taking cue delays in human-robot communication. *CEUR Workshop Proceedings*, *2059*, 19–29.
Duffy, B. R. (2003). Anthropomorphism and the social robot. *Robotics and Autonomous Systems*, *42*, 177–190. doi:10.1016/S0921-8890(02)00374-3
Eiser, J. R., & Eiser, J. R. (1986). *Social psychology: Attitudes, cognition and social behaviour*. Cambridge University Press, Cambridge, England.
Emmers-Sommer, T. M. (2004). The effect of communication quality and quantity indicators on intimacy and relational satisfaction. *Journal of Social and Personal Relationships*, *21*, 399–411. doi:10.1177/0265407504042839
Erel, H., Hoffman, G., & Zuckerman, O. (2018). *Interpreting non-anthropomorphic robots' social gestures*. Proceedings of the 2018 ACM/IEEE international conference on Human-Robot Interaction, Chicago, Illinois. ACM.
Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and Autonomous Systems*, *42*(3–4), 143–166. doi:10.1016/S0921-8890(02)00372-X
Forlizzi, J. (2007). *How robotic products become social products: An ethnographic study of cleaning in the home*. Proceedings of the ACM/IEEE international conference on Human-robot interaction (pp. 129–136). ACM.
Foster, M. E., Gaschler, A., Giuliani, M., Isard, A., Pateraki, M., & Petrick, R. (2012). *Two people walk into a bar: Dynamic multi-party social interaction with a robot agent*. Proceedings of the 14th ACM international conference on Multimodal interaction, Santa Monica, California (pp. 3–10). ACM.
Fukuda, T., Jung, M. J., Nakashima, M., Arai, F., & Hasegawa, Y. (2004). Facial expressive robotic head system for human-robot communication and its application in home environment. *Proceedings of the IEEE*, *92*, 1851–1865. doi:10.1109/JPROC.2004.835355
Galletta, A. (2013). *Mastering the semi-structured interview and beyond: from research design to analysis and publication*. New York, NY:NYU press.
Gemeinboeck, P., & Saunders, R. (2017). *Movement matters: How a robot becomes body*. Proceedings of the 4th international conference on Movement Computing, London, United Kingdom (p. 8). ACM.
Gibbs, G. R. (2008). *Analysing qualitative data*. Sage, Thousand Oaks, California.
Goffman, E. (1979). Footing. *Semiotica*, *25*, 1–30. doi:10.1515/semi.1979.25.1-2.1
Goffman, E. (1981). *Forms of talk*. University of Pennsylvania Press, Philadelphia, Pennsylvania.
Goodwin, C. (1981). *Conversational organization*. Interaction between speakers and hearers.
Groom, V., & Nass, C. (2007). Can robots be teammates?: Benchmarks in human–robot teams. *Interaction Studies*, *8*, 483–500.
Han, J., Campbell, N., Jokinen, K., & Wilcock, G. (2012). *Investigating the use of non-verbal cues in human-robot interaction with a Nao robot*. 2012 IEEE 3rd international conference on Cognitive Infocommunications (CogInfoCom), Kosice, Slovakia (pp. 679–683). IEEE.
Heider, F. (2013). *The psychology of interpersonal relations*. Psychology Press, East Sussex, England.
Henkel, Z., Bethel, C. L., Murphy, R. R., & Srinivasan, V. (2014). Evaluation of proxemic scaling functions for social robotics. *IEEE Transactions on Human-Machine Systems*, *44*, 374–385. doi:10.1109/THMS.6221037
Hoffman, G., Bauman, S., & Vanunu, K. (2016). Robotic experience companionship in music listening and video watching. *Personal and Ubiquitous Computing*, *20*, 51–63. doi:10.1007/s00779-015-0897-1
Hoffman, G., Birnbaum, G. E., Vanunu, K., Sass, O., & Reis, H. T. (2014). *Robot responsiveness to human disclosure affects social impression and appeal*. Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction, Bielefeld, Germany (pp. 1–8). ACM.
Hoffman, G., & Ju, W. (2014). Designing robots with movement in mind. *Journal of Human-Robot Interaction*, *3*, 78–95. doi:10.5898/JHRI.3.1.Hoffman
Hoffman, G., & Weinberg, G. (2011). Interactive improvisation with a robotic marimba player. *Autonomous Robots*, *31*, 133–153. doi:10.1007/s10514-011-9237-0
Hoffman, G., Zuckerman, O., Hirschberger, G., Luria, M., & Shani Sherman, T. (2015). *Design and evaluation of a peripheral robotic conversation companion*. Proceedings of the tenth annual ACM/IEEE international conference on Human-Robot Interaction, Portland, Oregon (pp. 3–10). ACM.
Iio, T., Yoshikawa, Y., & Ishiguro, H. (2017). *Starting a conversation by multi-robot cooperative behavior*. International conference on Social Robotics (pp. 739–748). Cham: Springer.
Johnson, D. W., & Johnson, R. (1985). Classroom conflict: Controversy versus debate in learning groups. *American Educational Research Journal*, *22*, 237–256. doi:10.3102/00028312022002237
Jung, M. F., Martelaro, N., & Hinds, P. J. (2015). *Using robots to moderate team conflict: The case of repairing violations*. Proceedings of the tenth annual ACM/IEEE international conference on Human-Robot Interaction, Portland, Oregon (pp. 229–236). ACM.

Kendrick, K. H., & Holler, J. (2017). Gaze direction signals response preference in conversation. *Research on Language and Social Interaction*, *50*, 12–32. doi:10.1080/08351813.2017.1262120

Kleinke, C. L. (1986). Gaze and eye contact: A research review. *Psychological Bulletin*, *100*, 78. doi:10.1037/0033-2909.100.1.78

Luria, M., Hoffman, G., Megidish, B., Zuckerman, O., & Park, S. (2016). Designing Vyo, a robotic Smart Home assistant: Bridging the gap between device and social agent. 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), New York, NY (pp. 1019–1025). IEEE doi:10.1109/ROMAN.2016.7745234

Luria, M., Hoffman, G., & Zuckerman, O. (2017). *Comparing social robot, screen and voice interfaces for smart-home control*. Proceedings of the 2017 CHI conference on human factors in computing systems, Denver, Colorado (pp. 580–628). ACM.

Matsusaka, Y., Fujie, S., & Kobayashi, T. (2001). *Modeling of conversational strategy for the robot participating in the group conversation*. Seventh European conference on speech communication and technology, Aalborg, Denmark.

Matsuyama, Y., Akiba, I., Fujie, S., & Kobayashi, T. (2015). Four-participant group conversation: A facilitation robot controlling engagement density as the fourth participant. *Computer Speech & Language*, *33*(1), 1–24. doi:10.1016/j.csl.2014.12.001

Matsuyama, Y., Taniyama, H., Fujie, S., & Kobayashi, T. (2010). *Framework of communication activation robot participating in multiparty conversation*. 2010 AAAI Fall Symposium Series, Arlington, Virginia.

Maxwell, G. M., Cook, M. W., & Burr, R. (1985). The encoding and decoding of liking from behavioral cues in both auditory and visual channels. *Journal of Nonverbal Behavior*, *9*, 239–263. doi:10.1007/BF00986883

Mohr, J., & Spekman, R. (1994). Characteristics of partnership success: Partnership attributes, communication behavior, and conflict resolution techniques. *Strategic Management Journal*, *15*, 135–152. doi:10.1002/(ISSN)1097-0266

Mori, M. (1970). The uncanny valley. *Energy*, *7*, 33–35.

Morse, J. M. (1995). *The significance of saturation*. Sage, Thousand Oaks, California.

Mutlu, B., Kanda, T., Forlizzi, J., Hodgins, J., & Ishiguro, H. (2012). Conversational gaze mechanisms for humanlike robots. *ACM Transactions on Interactive Intelligent Systems (Tiis)*, *1*, 12.

Mutlu, B., Shiwa, T., Kanda, T., Ishiguro, H., & Hagita, N. (2009). *Footing in human-robot conversations: How robots might shape participant roles using gaze cues*. Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, La Jolla, California (pp. 61–68). ACM.

Mwangi, E. N., Barakova, E. I., Diaz, M., Mallofré, A. C., & Rauterberg, M. (2017). *Who is a better tutor?: Gaze hints with a human or humanoid tutor in game play*. Proceedings of the Companion of the 2017 ACM/IEEE international conference on Human-Robot Interaction, Vienna, Austria (pp. 219–220). ACM.

Nagao, K., & Takeuchi, A. (1994). Social interaction: Multimodal conversation with social agents. *AAAI*, *94*, 22–28.

Nichols, A. L., & Maner, J. K. (2008). The good-subject effect: Investigating participant demand characteristics. *The Journal of General Psychology*, *135*, 151–166. doi:10.3200/GENP.135.2.151-166

Oliveira, R., Arriaga, P., Alves-Oliveira, P., Correia, F., Petisca, S., & Paiva, A. (2018). *Friends or foes?: Socioemotional support and gaze behaviors in mixed groups of humans and robots*. Proceedings of the 2018 ACM/IEEE international conference on Human-Robot Interaction, Chicago, Illinois (pp. 279–288). ACM.

Opdenakker, R. (2006). Advantages and disadvantages of four interview techniques in qualitative research. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, *7*, 4.

Otsuka, K., Yamato, J., Takemae, Y., & Murase, H. (2006). *Quantifying interpersonal influence in face-to-face conversations based on visual attention patterns*. CHI'06 Extended Abstracts on Human Factors in Computing Systems, Montréal, Canada (pp. 1175–1180). ACM.

Pacchierotti, E., Christensen, H. I., & Jensfelt, P. (2006). *Design of an office-guide robot for social interaction studies*. 2006 IEEE/RSJ international conference on Intelligent Robots and Systems, Beijing, China (pp. 4965–4970). IEEE.

Parlitz, C., Hägele, M., Klein, P., Seifert, J., & Dautenhahn, K. (2008). *Care-o-bot 3-rationale for human-robot interaction design*. Proceedings of 39th International Symposium on Robotics (ISR) (pp. 275–280). Seul, Korea.

Riek, L. D. (2012). Wizard of oz studies in hri: A systematic review and new reporting guidelines. *Journal of Human-Robot Interaction*, *1*, 119–136. doi:10.5898/JHRI.1.1.Riek

Robins, B., Dautenhahn, K., Te Boekhorst, R., & Billard, A. (2005). Robotic assistants in therapy and education of children with autism: Can a small humanoid robot help encourage social interaction skills? *Universal Access in the Information Society*, *4*, 105–120. doi:10.1007/s10209-005-0116-3

Sakamoto, D., & Ono, T. (2006). *Sociality of robots: Do robots construct or collapse human relations?*. Proceedings of the 1st ACM SIGCHI/SIGART conference on Human-robot interaction, Salt Lake City, Utah (pp. 355–356). ACM.

Shah, J., Wiken, J., Williams, B., & Breazeal, C. (2011). *Improved human-robot team performance using chaski, a human-inspired plan execution system*. Proceedings of the 6th international conference on Human-robot interaction, Lausanne, Switzerland (pp. 29–36). ACM.

Shen, S., Slovak, P., & Jung, M. F. (2018). *Stop. I see a conflict happening.: A robot mediator for young children's interpersonal conflict resolution*. Proceedings of the 2018 ACM/IEEE international conference on Human-Robot Interaction, Chicago, Illinois (pp. 69–77). ACM.

Sidner, C. L., Lee, C., Kidd, C. D., Lesh, N., & Rich, C. (2005). Explorations in engagement for humans and robots. *Artificial Intelligence*, *166*, 140–164. doi:10.1016/j.artint.2005.03.005

Simons, T., Pelled, L. H., & Smith, K. A. (1999). Making use of difference: Diversity, debate, and decision comprehensiveness in top management teams. *Academy of Management Journal*, *42*, 662–673.

Spexard, T., Li, S., Wrede, B., Fritsch, J., Sagerer, G., Booij, O., … Krose, B. (2006). *BIRON, where are you? Enabling a robot to learn new places in a real home environment by integrating spoken dialog and visual localization*. 2006 IEEE/RSJ international conference on Intelligent Robots and Systems, Beijing, China (pp. 934–940). IEEE.

Takayama, L., Dooley, D., & Ju, W. (2011). *Expressing thought: Improving robot readability with animation principles*. 2011 6th ACM/IEEE international conference on Human-Robot Interaction (HRI), Lausanne, Switzerland (pp. 69–76). IEEE.

Takayama, L., & Pantofaru, C. (2009). *Influences on proxemic behaviors in human-robot interaction*. 2009 IEEE/RSJ international conference on Intelligent Robots and Systems, St Louis, St Louis (pp. 5495–5502). IEEE.

Tan, X. Z., Vázquez, M., Carter, E. J., Morales, C. G., & Steinfeld, A. (2018). *Inducing bystander interventions during robot abuse with social mechanisms*. Proceedings of the 2018 ACM/IEEE international conference on Human-Robot Interaction, Chicago, Illinois (pp. 169–177). ACM.

Tanaka, F., & Ghosh, M. (2011). *The implementation of care-receiving robot at an English learning school for children*. Proceedings of the 6th international conference on Human-robot interaction, Lausanne, Switzerland (pp. 265–266). ACM.

Taylor, S. E., & Fiske, S. T. (1978). Salience, attention, and attribution: Top of the head phenomena. In *Advances in experimental social psychology* (Vol. 11, pp. 249–288). Elsevier, Amsterdam, Netherlands

Tennent, H., Shen, S., & Jung, M. (2019). *Micbot: A peripheral robotic object to shape conversational dynamics and team performance*. 2019 14th ACM/IEEE international conference on Human-Robot Interaction (HRI), Daegu, Korea (pp. 133–142). IEEE.

Vázquez, M., Carter, E. J., McDorman, B., Forlizzi, J., Steinfeld, A., & Hudson, S. E. (2017). *Towards robot autonomy in group conversations: Understanding the effects of body orientation and gaze*. Proceedings of the 2017 ACM/IEEE international conference on Human-Robot Interaction, Vienna, Austria (pp. 42–52). ACM.

Verplanck, W. S. (1955). The control of the content of conversation: Reinforcement of statements of opinion. *The Journal of Abnormal and Social Psychology*, *51*(3), 668. doi:10.1037/h0046514

Vertegaal, R., Slagter, R., Van der Veer, G., & Nijholt, A. (2001). Eye gaze patterns in conversations: There is more to conversational agents than meets the eyes. Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 301–308). ACM. doi:10.1145/365024

Vertegaal, R., Slagter, R., Van der Veer, G., & Nijholt, A. (2001). *Eye gaze patterns in conversations: There is more to conversational agents than meets the eyes*. Proceedings of the SIGCHI conference on Human factors in computing systems, Seattle, Washington (pp. 301–308). ACM.

Wu, Y. H., Fassert, C., & Rigaud, A. S. (2012). Designing robots for the elderly: Appearance issue and beyond. *Archives of Gerontology and Geriatrics*, *54*, 121–126. doi:10.1016/j.archger.2011.02.003

Zaga, C., de Vries, R. A., Li, J., Truong, K. P., & Evers, V. (2017). *A simple nod of the head: The effect of minimal robot movements on children's perception of a low-anthropomorphic robot*. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Denver, Colorado (pp. 336–341). ACM.

Zuckerman, O., & Hoffman, G. (2015). *Empathy objects: Robotic devices as conversation companions*. Proceedings of the ninth international conference on tangible, embedded, and embodied interaction, Stanford, California (pp. 593–598). ACM.