The robot-to-robot service encounter: an examination of the impact of inter-robot warmth

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Abstract
Purpose – This study aims to examine humans' reactions to service robots' display of warmth in robot-to-robot interactions – a setting in which humans' impressions of a service robot will not only be based on what this robot does in relation to humans, but also on what it does to other robots.
Design/methodology/approach – Service robot display of warmth was manipulated in an experimental setting in such a way that a service robot A expressed low versus high levels of warmth in relation to another service robot B.
Findings – The results indicate that a high level of warmth expressed by robot A *vis-à-vis* robot B boosted humans' overall evaluations of A, and that this influence was mediated by the perceived humanness and the perceived happiness of A.
Originality/value – Numerous studies have examined humans' reactions when they interact with a service robot or other synthetic agents that provide service. Future service encounters, however, will comprise also multi-robot systems, which means that there will be many opportunities for humans to be exposed to robot-to-robot interactions. Yet, this setting has hitherto rarely been examined in the service literature.

Keywords Customer service, Experimental design, Artificial intelligence

Paper type Research paper

1. Introduction

It has become increasingly common for customers to receive service from various synthetic agents, such a chatbots and embodied robots (Belanche *et al.*, 2020; Lu *et al.*, 2020). This development is predicted to accelerate, which means that the traditional service encounter between a human customer and a human employee is likely to become less frequent (Mende *et al.*, 2019). It also means that new labels for robot-provided service may be needed – such as "rService" (Murphy *et al.*, 2019). Academic researchers and managers in firms who want to identify synthetic agent behavior with a positive impact on customers have access to a wealth of information, because humans' reactions to non-human agents have been examined in a large number of studies. Moreover, humans typically apply a scheme for human-to-human interactions in interactions with humanlike non-humans (Broadbent, 2017; Epley, 2018; Reeves and Nass, 1996), so many of the characteristics of human employees that make human customers satisfied in service encounters are likely to make them satisfied also when non-human agents have (or are imbued with) such characteristics. For example, when a virtual agent displays happiness in a service encounter, it produces similar reactions to when a human employee does this (Söderlund *et al.*, 2021).

However, accelerated levels of automation comprises also the emergence of multi-robot systems, which may behave more robustly and effectively than a single robot (Liu *et al.*, 2013; Tuci *et al.*, 2018). Applications include, for example, search and rescue tasks, transportation, detection of forest fires and inventory handling – and all of them require robot-to-robot interaction in one way or another (Jawhar *et al.*, 2018; Tuci *et al.*, 2018). Multi-robot systems can be expected also in settings involving service to consumers, which means that consumers in the near future are likely to become exposed to robot-to-robot interactions – such as when the customer encounters a robot that subsequently "hands over" the customer to a second robot (Tan *et al.*, 2019) and when a human asks two robots to carry out a task that requires inter-robot communication (Williams *et al.*, 2015). Robots talking to each other in a service environment may also be used to transmit information to the customer who can "overhear" what they say (Pan *et al.*, 2015; Sakamoto *et al.*, 2009). In the present study, the robot-to-robot setting involves a situation in which a human asks a robot for service and this robot turns to – and interacts with – a second robot to fulfill the request. The present study also focuses on how the second robot's treatment

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of the first robot affects humans' reactions to the second robot (which is referred to as the target robot).

In general terms, then, this study deals with a social perception setting in which an observer is provided with information about a target individual A in terms of A's behavior *vis-à-vis* another individual B. This type of setting has been under-researched for human–human interactions, both in social psychology and in service encounter research, because research in these fields has typically applied a strict dyadic perspective (i.e. no other individual is present beyond the observer and the target individual A). Nevertheless, a main assumption in the present study, when A and B are humans, is that information about A's social behavior in relation to B is likely to affect the observer's judgment of A. This assumption is based on previous studies indicating that information about A's relations to third parties can influence the observer. If person A has a physically attractive partner B, for example, this is likely to have an impact on the observer's view of A (Sigall and Landy, 1973). Given again that humans react to humanlike non-humans in ways that are similar to reactions to humans (Epley, 2018; Reeves and Nass, 1996), it is assumed in the present study that information about A's behavior in relation to B will influence the observer's judgment of A also in the case when A and B are service robots.

Many behaviors of a target robot A *vis-à-vis* another robot B may influence an observer's judgments of A, and this study examines one specific behavior: the level of warmth displayed by robot A. The main rationale why warmth was selected as a focal variable in this study of service robots is that warmth is intimately related to one of the fundamental dimensions of service quality in human-to-human contexts, namely, the functional dimension of service quality. This dimension has to do with *how* the customer receives a service as opposed to *what* the customer receives in terms of technical quality (Grönroos, 1984). As this distinction was launched, many studies have shown that warmth-related aspects of an employee in a service encounter contribute positively to the evaluation of the employee and to the overall evaluation of the firm that the employee represents (Bitner *et al.*, 1990; Sundaram and Webster, 2000; Söderlund, 2020). Thus warmth, as a characteristic of an individual service provider, is a variable with a well-documented ability to influence downstream variables considered important in service settings comprising human employees. Moreover, in a setting with service robots, Wirtz *et al.* (2018) have suggested that customer acceptance of such robots is likely to be determined not only by factors related to easiness of use and perceived usefulness, but also by social–emotional and relational elements, and warmth could be seen as one component among the relational elements.

The specific purpose of the present study is to explore if the influence of warmth on overall evaluations would materialize also in the case of robot-to-robot interactions and, if so, to examine if it can be explained by a set of mediator variables. To this end, an experiment was used to manipulate the behavior of an embodied target service robot (low warmth vs high warmth) that interacted with another service robot, and the main dependent variable was the overall evaluation of the warmth-displaying target robot.

This examination aims to address several gaps in the existing literature. First, the number of studies addressing humans' reactions to robot-to-robot interactions has so far been limited, despite the fact that service robots are moving away from being standalone machines (Murphy *et al.*, 2019). Second, only a few existing studies of robots in service and marketing contexts, such as Mende *et al.* (2019), have examined customers' reactions to embodied, humanoid service robots (Xiao and Kumar, 2019), despite the observation that embodiment per se is likely to produce other effects than a bodiless appearance (Broadbent, 2017). That is to say, the typical assessment of the impact of non-human agents on humans in service settings involves two-dimensional (and thus screen-based) synthetic agents. By contrast, the present study involves embodied service robots. Third, several existing studies have examined humans' reactions to various aspects of non-verbal activities by synthetic agents (Lin and Lin, 2017), but the present study examines the influence of robots' use of (human) language when they are engaged in robot-to-robot interactions. Service researchers have called for more studies of the influence of language in service encounters (Holmqvist *et al.*, 2017), and the present study can be seen as a response to such calls, in the sense that it manipulates the impact of what a robot says (rather than if it speaks English or other languages) on perceptions of the robot's warmth.

2. Theoretical framework and hypotheses

The thesis to be elaborated on in the sections below is that warmth expressed by a target robot in relation to another robot affects a human observer's overall evaluation of the target robot. The latter response was chosen as the main dependent variable because – in human-to-human service encounters – the service provider typically *is* the service from the customer's point of view (Bitner *et al.*, 1990). Thus, the evaluation of the individual service provider is likely to be a main determinant of the overall evaluation of the service itself and the firm that the provider represents.

As a theoretical point of departure, it is assumed that humans have a tendency to perceive non-human agents as having human characteristics. This is often referred to as anthropomorphism (Damiano and Dumouchel, 2018; Epley *et al.*, 2008; Kim and Sundar, 2012), which is particularly likely to materialize if the non-human agent is similar to a real human (Epley, 2018). Examples of similarities that can trigger anthropomorphism is when the agent has a voice, a body with two arms and two legs, a human name and appears to have mind-related capabilities such as agency and emotionality. Several explanations of anthropomorphism have been offered in the existing literature, and one influential model suggests that it facilitates the satisfaction of fundamental human needs of controlling and understanding others as well the need for social connections (Epley *et al.*, 2008). In any event, anthropomorphism serves as a dominant conceptual component in most studies of how humans react to synthetic agents (particularly when a study deals with reactions that occur also in human-to-human interactions, such as liking, trust and perceived competence), because this allows the researcher to use theories originally developed for a human-to-human context. The present study uses the same approach, in the sense that the hypotheses below have been built with material from social perception theories with an information processing framework (i.e. reactions are seen as related to each other in terms of causal chains).

2.1 Human warmth and robot warmth

In human-to-human settings, warmth has to do with a person's character along an overall cold–warm dimension. Typically, a person's position on this continuum is assumed to be indicative of his or her intent for good or ill (Fiske *et al.*, 2007), and thus, it helps us in distinguishing friends from foes (Cuddy *et al.*, 2011). Presumably, the capability to be a warm person, and to be able to perceive others as warm, has evolved to facilitate cohesive relations in groups and, in particular, paternal investment in children (MacDonald, 1992). Indeed, the higher capacity for being warm and having better means to display it – and recognizing it in others – may explain why it was *Homo sapiens* who prevailed, while the other human species became extinct (Hare, 2017). Given this, it is not surprising that warmth is assumed to be a universal perception dimension (Fiske *et al.*, 2007; Judd *et al.*, 2005) and that warmth judgments are primary in social perception settings; warmth judgments are made before other judgments and carry a high weight in affective and behavioral reactions (Fiske *et al.*, 2007).

Several specific target person behaviors have been identified as antecedents to observers' assessments of a target person's warmth. They include smiles; body, head, arm and hand movements; eye contact; speech rate; and a rhythmic vocal tone (Bayes, 1972; Lin and Lin, 2017). The human perception apparatus seems to have a high sensitivity to warmth, because even a person's username (e.g. bareco@gmail.com) can influence how he or she is perceived in terms of warmth (Garrido *et al.*, 2019). In any event, factor-analytic studies provide additional clues about what contributes to perceptions of a person as warm, namely, behavior that signals honesty, sincerity, tolerance and helpfulness (Fiske *et al.*, 2007). Moreover, in a service encounter setting, several studies show that female employees tend to be perceived as higher in warmth than male employees (Andrzejewski and Mooney, 2016; Smith *et al.*, 2016). Of particular importance for the present study (and for its manipulation of robot warmth) is that previous research also shows that the content of language used by a person in an interaction provides observers with clues about the person's warmth (Bayes, 1972). For example, language elements in a conversation signaling high warmth comprise saying "hello," expressing gratitude, making indirect requests and statements as well as usage of qualifying markers (Jeong *et al.*, 2019).

Given that humans easily imbue humanlike non-humans with human characteristics (Epley, 2018; Reeves and Nass, 1996), and given that warmth is a universal dimension in perceptions of humans, one would expect that synthetic agents with humanlike characteristics can be perceived along a warmth dimension. Several studies indicate that this is indeed the case. For example, Nguyen *et al.* (2015) created virtual agents (modeled after stereotypic humans who differ in warmth) that were able to influence observers' perceptions of the agents' warmth, and Bergmann *et al.*'s (2012) virtual agents, made to look like robots, boosted perceived warmth when they were provided with the ability to use gestures. Moreover, Hoffmann *et al.* (2020) exposed participants to an embodied shopping robot whose language (machinelike vs humanlike) affected perceptions of robot warmth, which, in the next step, influenced the liking of the robot.

With this as a point of departure, it is assumed that embodied robots can be perceived as having more or less warmth. Assuming also that humanlike non-humans targets tend to elicit reactions similar to human targets, and given that the warmth of a human target person has been found to be positively correlated with others' liking (Wortman and Wood, 2011) and others' overall evaluations of this person (Abelson *et al.*, 1982; Wojciszke *et al.*, 1998), a similar pattern is expected for robots. Thus, it is expected that the more warmth a target robot displays in an interaction with another robot, the more positively it is evaluated. The impact of perceived warmth on evaluations, however, can be assumed to be mediated, and two routes of mediation are discussed below (Figure 1). Please notice the following: the present study deals with a situation in which two robots interact, the hypotheses are about how one of them is perceived by humans, and to be able to make distinctions between robots in this situation the robot that is hypothesized to evoke reactions is referred to as the target robot.

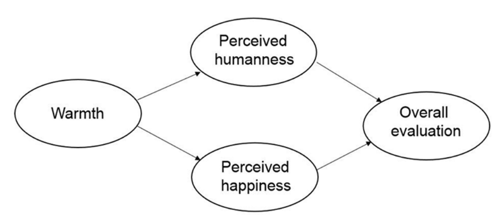
2.2 The perceived humanness route

Perceived humanness has to do with the extent to which an individual is seen as having characteristics that are typical for humans. This has been referred to as the "human nature" aspect of humanness (Haslam, 2006). As a perceptual dimension, both real humans (Epley *et al.*, 2013; Söderlund, 2020) and non-humans (Bastian *et al.*, 2012; Kim and Sundar, 2012; Powers and Kiesler, 2006) have been assessed in terms of perceived humanness.

Warmth has been conceptualized as one of several fundamental facets of being human (Haslam and Bain, 2007); people see warmth-related traits as deeply rooted aspects of a person (Riis *et al.*, 2008). Indeed, to be warm in interactions with others can be seen as being mindful about a main general norm that humans are supposed to do good things, not bad things, in inter-human relations (Baumeister *et al.*, 2001). Thus, with this view, warmth has a morality component (Banks, 2020). And in general, a positive association is expected between a target person's perceived compliance with social norms and the perceived humanness of the person, which means that norm-violators can be expected to be dehumanized (Bastian *et al.*, 2013).

Therefore, it is assumed here that perceptions of an agent's warmth contribute positively to perceptions of the agent's humanness. Empirical results for human target persons show that perceived warmth of a person indeed has a positive influence on the perceived humanness of the person

Figure 1 Overview of the assumed associations between the variables in the hypotheses



(Söderlund, 2020). Given that humans tend to respond to (humanlike) non-humans in ways that resemble responses to humans, the following is hypothesized for the situation when the agent is a robot and is observed in an interaction with another robot:

H1. Target robot display of warmth in relation to another robot has a positive influence on the perceived humanness of the target robot.

Then, in the next step of the observer's processing of information, it is expected that the perceived humanness of an agent has a positive influence on the overall evaluation of the agent. One main reason is that humans in general have an overall positive rather than a negative charge (Sears, 1983). This is likely to be a function of the inherently social nature of humans; we humans need other humans for both practical and existential issues (Epley *et al.*, 2008). From an evolutionary point of view, then, it seems reasonable that humans should be hardwired to evaluate other humans in positive rather than negative terms. Moreover, if an agent is perceived as humanlike it is likely that a human observer would perceive himself or herself as similar to the agent, and perceived similarity typically has a positive influence on evaluations (Cialdini, 2007). It is also possible that the anthropomorphization of a non-human agent increases the extent to which humans find it comfortable to rely on the agent (Shi *et al.*, 2020), which in turn can boost evaluations of the agent.

In terms of findings in previous studies, a positive association between the extent to which a human person is imbued with humanness and evaluations of the person has been found by Kozak *et al.* (2006) and Söderlund (2020). Moreover, in consumer contexts, several studies have identified a positive influence of anthropomorphizing an offer on evaluations of the offer (Aggarwal and McGill, 2007; Delbaere *et al.*, 2011; Rauschnabel and Ahuvia, 2014). Some authors have suggested that this association may be non-linear in the case of robots, in the sense that increases in a robot's humanlike appearance may lead to increased liking up to a point after which a too humanlike appearance becomes uncanny and results in reduced liking. However, empirical studies have produced inconsistent results regarding this uncanny valley hypothesis (Cheetham *et al.*, 2011; Gray and Wegner, 2012; Kätsyri *et al.*, 2015), so it is expected in the present study that the more humanlike a robot is perceived to be in its interaction with another robot, the more positive it is evaluated:

H2. The perceived humanness of a target robot has a positive influence on the overall evaluation of the target robot.

2.3 The happiness route

In human-to-human interactions, several studies suggest that a target person's smile versus no smile (Bayes, 1972; Hack, 2014; Nelson *et al.*, 1988; Reis *et al.*, 1990), and a big smile versus a small smile (Wang *et al.*, 2017), can boost the person's perceived warmth or warmth-related traits. Presumably, then, if a robot could smile in a humanlike way, its smile would enhance perceptions of its warmth. So far, however, few contemporary embodied robots have a mouth, and thus, they cannot smile like humans. Moreover, a smile is not necessarily a good indicator of happiness (Söderlund and Berg, 2019), and other behaviors than smiles can contribute to perceived happiness. In the present study, and for perceptions of robots that cannot smile, but can communicate their warmth in humanlike language, it is instead assumed that a robot's display of warmth can signal that the robot is happy. Thus, in the present study, and given the primacy of warmth in relation to other judgments (Fiske *et al.*, 2007; Garrido *et al.*, 2019), warmth, not happiness, is assumed to be the antecedent.

Why, then, would warmth perceptions influence happiness perceptions? One reason is that these two characteristics are typically positively correlated in observers' assessments of human target persons (cf. Fiske *et al.*, 2007; Goodwin *et al.*, 2014). In the absence of visible clues about another person's happiness, repeated exposure to warmth–happiness covariations is, therefore, expected to serve as the basis for the inference that a warm person is likely to be happy.

Another reason is based on warmth as being one the most important traits that we humans want others to perceive us to have (Son Holoien and Fiske, 2013). Communicating that one is a warm person, however, is not always successful, and when it fails, it is expected to be followed by sadness (Çelik *et al.*, 2013). If successful attempts to communicate that one is high on warmth is followed by happiness, egocentric experience of this link may carry over to beliefs that others' warmth is a predictor of their happiness.

Moreover, these response patterns are assumed to be carried over also to a setting in which the target agent is a humanlike non-human. Thus, it is expected that robot display of warmth can enhance perceptions of robot happiness. Several observers, however, have noted that service robots are not able to feel real emotions, and that this is likely to be the case also in the foreseeable future (Wirtz *et al.*, 2018), and one would assume that the same belief is held also by the general public (and by participants in studies of robots). Given this view, robot happiness (as a true emotional state) is not a meaningful variable in empirical assessments of antecedents of robot happiness. However, given again the easiness by which humans imbue non-human agents with human characteristics, robots and other synthetic agents can be *perceived* as more or less happy (cf. Söderlund *et al.*, 2021). Therefore, given the arguments about warmth as an antecedent to happiness perceptions in human-to-human settings, and in a situation in which a target robot is observed in an interaction with another robot, the following is hypothesized:

H3. Target robot display of warmth in relation to another robot has a positive influence on the perceived happiness of the target robot.

In the subsequent step in the observer's information processing activities, it is assumed that perceptions of an agent as happy has a positive influence on the overall evaluation of the agent. One general reason is that emotions tend to be contagious in social settings, so the perceived happiness of an agent boosts the happiness of the observer (Hatfield *et al.*, 1993), which in the next step can inform evaluations of the emotion-generating agent in a valence-congruent way (Forgas, 1995). Moreover, when a human agent is representing a firm in a service setting, display of happiness is likely to be viewed as a norm, because many service firms have, over the years, stressed the importance of employees appearing happy in interactions with customers (Söderlund and Berg, 2019). Most customers, then, have been subject to prolonged exposure over time to service employees instructed to display happiness in service encounters, meaning that most customers are likely to view employee display of happiness as an important element of a service job. And, when such displays do occur, it is assumed here that they signal that the employee knows what he or she is doing, which in turn is expected to be rewarded with positive evaluations. Empirical evidence indicating that a happy human service employee is positively evaluated is provided by, for example, Söderlund and Berg (2019). Given again that humans tend to respond to humanlike non-human agents similarly to the responses to real humans, it is expected that a happy-appearing non-human can have a positive impact on evaluations. Söderlund *et al.* (2021) provide evidence for this in the case of virtual representatives. Hence the following is hypothesized for the situation in which a target robot is observed in an interaction with another robot:

H4. The perceived happiness of a target robot has a positive influence on the overall evaluation of the target robot.

2.4 Robot warmth and the overall evaluation of the robot

Taken together, the arguments related to *H1–H4* above imply that a target robot's display of warmth in relation to another robot has a mediated influence on the overall evaluation of the target robot (cf. Figure 1). To explicitly assess the net outcome, the following is hypothesized for the situation in which a target robot is observed in an interaction with another robot:

H5. The display of warmth by the target robot to another robot has a positive influence on the overall evaluations of the target robot.

3. Research method

3.1 Research design, stimulus material and participants

A between-subjects experiment was used to manipulate service robot warmth (low vs high) with a Wizard of Oz approach (cf. Broadbent, 2017; Riek, 2012). The basis for the manipulations comprised the creation of an interaction situation involving one human and two service robots. A script for such a situation, including human-to-robot and robot-to-robot dialogue, was developed by the author. In this script, the interactions took place in an office environment in which a human asked for service from a service robot, which required this robot to interact with a second service robot (the target robot). More specifically, the human asked the first robot to go to a kitchen and check if new fruit had arrived. When this robot arrived in the kitchen, it met the target robot who was in charge of kitchen activities, and the first robot needed to interact verbally with the target robot to complete the task. The organization of activities and division of work in this setting means that the human can be seen as a principal who delegates a task to an agent (cf. Bergen *et al.*, 1992). Thus, in the present study, the human initiated what lead to a robot-to-robot interaction rather than passively observed a robot-to-robot interaction initiated by robots (as in Sakamoto *et al.*, 2009). Moreover, in the script, the robots were provided with the main characteristics of a general service robot. That is to say, a service robot has a body that can move; it can act autonomously in an everyday environment; and it can receive (and understand) instructions, and respond to them, in human language (de Graaf *et al.*, 2019; Murphy *et al.*, 2019).

In the next step, a video was produced to depict the scripted situation with two robots (a 26.5 cm JJRC *R*2 robot and a 41 cm Orbit Bot), which were given synthetic voices by the means of a software that translates text to speech. The latter was inspired by the creation of interacting robot stimuli in Pan *et al.* (2015). Two versions of the video were created. In one version, the target robot displayed a low level of warmth *vis-à-vis* the robot that the human had sent to the kitchen; in the second version, the target robot displayed a high level of warmth. More specifically, the content of the target robot's part of the conversation was manipulated, while the human's and the other robot's parts were kept constant. Thus, it was how the target robot talked to the other robot that was subject to differences between the two versions. Low warmth was indicated by no greeting phrase, egocentric focus and direct statements and questions; high warmth was indicated by a greeting phrase, less egocentric focus and indirect statements and questions (see Experimental stimuli). Jeong *et al.* (2019) have used a similar approach to manipulating warmth by the language used in a human–human negotiation setting. Video-based stimuli have been used in research on perceptions of robots by, for example, Gazzola *et al.* (2007), Kupferberg *et al.* (2011) and Mende *et al.* (2019).

As a pretest of the language content, the two versions of the target robot's part in the robot-to-robot conversation were analyzed with the Linguistic Inquiry and Word Count (LIWC) software (cf. Tausczik and Pennebaker, 2010). More specifically, and with the assumption that positively charged language indicates a higher level of warmth than negatively charged language, LIWC was used to compute the emotional tone in the two versions of the text. The emotional tone can take on values in the 0–100 range (the higher the value, the more positive the tone). In the present material, and for the target robot, the emotional tone was lower for the low warmth version (32.64) than for the high warmth version (66.89). This pretest, thus, suggested that the target robot's language in the two versions had the potential to be perceived as different.

The participants in the experiment were recruited from Prolific, an online panel built for research purposes (cf. Palan and Schitter, 2018). They were randomly allocated to watch one of the two video versions and answered a set of subsequent questions comprising measures of the variables in the hypotheses. In total, 372 participants completed the study. However, 14 of these participants failed to respond correctly to one or several of the included attention check items, and they were removed. Thus, the analysis was based on those that remained (n = 358, M_{age} = 34.33; 221 women, 134 men and three other). Of these, 178 were exposed to the low warmth version of the video, while 180 were exposed to the high warmth version.

3.2 Measurements

All items were scored on ten-point scales, and Cronbach's α (CA), composite reliability (CR) and average extracted variance (AVE) were used to assess the properties of the multiitem measures. In addition, discriminant validity with respect to warmth, perceived humanness, perceived happiness and overall evaluations was assessed in terms of the heterotrait-monotrait ratio of correlations (all ratios were < 0.90). SmartPLS 3.0 was used for these assessments. Please notice again that the hypotheses are about reactions to one of the robots (the target robot) in a robot-to-robot interaction. In the videos, the target robot was responsible for various kitchen activities, so it was referred to as "the kitchen robot" in the questions to the participants (and a still image of this robot appeared with the questions to make it clear which robot the participants should answer questions about).

Warmth was measured with the question "What is your view of the kitchen robot in terms of the following characteristics?," followed by the adjective pairs "cold-warm," "unfriendly-friendly," "impolite-polite," "unkind-kind" and "harsh-gentle" (CA = 0.93, CA = 0.94, AVE = 0.77). Similar items, used for perceptions of human target persons, have been used by, for example, Smith *et al.* (2016), Wang *et al.* (2017), Wojciszke *et al.* (1998) and Zawisza and Pittard (2015).

The first mediator variable, *perceived humanness*, was measured with the items "The kitchen robot appeared very much as a human," "The kitchen robot was humanlike" and "The kitchen robot acted like humans typically do" (1 = do not agree at all, 10 = agree completely; CA = 0.90, CR = 0.94, AVE = 0.84). Similar items have been used by, for example, Aggarwal and McGill (2007), Choi *et al.* (2019) and Thompson *et al.* (2011). The second mediator, *perceived happiness*, was assessed with the adjective pair "the kitchen robot was sad-the kitchen robot was happy." Such adjective pairs to assess happiness of non-human agents have been used in previous research by, for example, Söderlund *et al.* (2021).

Finally, the participants' *overall evaluations* were measured with the question "What is your overall evaluation of the kitchen robot?," followed by the adjective pairs "bad-good," "dislike it-like it" and "unpleasant-pleasant" (CA = 0.94, CR = 0.96, AVE = 0.89). Items of this type are common to capture consumers' overall evaluations of an object, in terms of the attitude toward the object, and they have been used by, for example, MacKenzie and Lutz (1989).

The means and standard deviations for these variables, and the zero-order correlations, are reported in Table 1.

4. Analysis and results

A manipulation check with the warmth variable showed that it reached a lower level in the low warmth condition ($M = 3.90$) than in the high warmth condition ($M = 6.73$). This difference was significant ($t = 16.34$, $p < 0.01$). Thus, the manipulation worked as intended.

H1–H4 were tested simultaneously with SmartPLS 3.0. The proposed model with the four links represented by *H1–H4* (Figure 1) had a good level of fit with the data (SMRM = 0.07). The path coefficients are reported in Table 2; all of them were significant, which indicates support for *H1–H4*.

To explicitly examine the two routes of mediated influence, the structural equation model-based approach suggested by Nitzl *et al.* (2016) and Sarstedt *et al.* (2020) was followed. That is to say, one link was added to the proposed model (i.e. a direct link between warmth and overall evaluations) to be able to control for a direct effect, and if the indirect links are significant, to assess the type of mediation. With this approach, mediation is at hand if there is a significant indirect influence of an independent variable on a dependent variable. This, in turn, is indicated by the confidence interval for the coefficient for the indirect effect (it should not comprise a zero). Nitzl *et al.* (2016) recommends a biased-corrected confidence interval for the assessment, and this was used here. This analysis showed that there was a significant indirect effect for both the warmth–humanness–overall evaluation chain ($b = 0.08$, $p < 0.01$) and the warmth–happiness–overall evaluation chain ($b = 0.13$, $p < 0.01$). Moreover, the direct impact of warmth on overall evaluations was significant ($b = 0.39$, $p < 0.01$), which indicates that complementary mediation was at hand (cf. Zhao *et al.*, 2010). The proposed model with the additional, direct link between warmth and overall evaluations explained 48% of the variance in overall evaluations.

As for *H5*, a comparison of the overall evaluation level between the two conditions showed that it was lower in the low warmth condition ($M = 5.35$) than in the high warmth condition ($M = 6.99$). This difference was significant ($t = 7.45$, $p < 0.01$), which provides supports for *H5*.

5. General discussion

5.1 Contributions

Several observers are confident that service robots will alter the workforce and the marketplace, and that the extent to which such robots are humanlike will be a critical factor that influences the interactions between humans and service robots (Broadbent, 2017; Murphy *et al.*, 2019). This assumption has inspired copious studies that examine humanlike attributes of robots and other synthetic agents (e.g. voice and face) as well as the effects of such agents on psychological response variables that occur in human-to-human interactions (e.g. trust, liking and perceived competence). Given humans' strong tendency to anthropomorphize what is humanlike, and given that anthropomorphization facilitates both understanding and control (Epley *et al.*, 2008), research comprising humanlike attributes of robots, and their effects in terms of responses

Table 1 Means, standard deviations and the zero-order correlations[a] for the variables in the hypotheses

Variable	*M*	*SD*	1	2	3
1. Warmth	5.48	2.14			
2. Humanness	3.43	1.97	0.32		
3. Happiness	5.65	1.92	0.49	0.31	
4. Overall evaluation	6.27	2.22	0.57	0.44	0.53

Notes: [a]All correlations are significant ($p < 0.01$)

Table 2 Path coefficients for *H1–H4*

Hypothesis	Path coefficient	*t*	*p*
H1: Warmth – humanness	0.34	6.53	< 0.01
H2 Humanness – overall evaluation	0.23	5.64	< 0.01
H3: Warmth – happiness	0.50	11.68	< 0.01
H4: Happiness – overall evaluation	0.27	5.34	< 0.01

typically occurring in relation to humans, seems to make sense both for designers of robots and those whose task it is to understand the user's interaction with robots.

So far, however, most existing studies of humans' reactions to robots have been conducted in a dyad setting comprising one human and one robot. By contrast, the present study examined humans' reactions to robot-to-robot interactions, which are expected to become increasingly prevalent when multi-robot systems are implemented in consumer service settings. More specifically, the present study examined reactions to one particular target robot in a situation allowing for perceptions of this robot to be formed on the basis of how it interacted with another robot. This approach was used as an attempt to mirror that humans' perceptions of humans are often fueled by observations of how a particular target person is related to other persons in terms of conversation content and other behaviors. Incidentally, this view of how perceptions of one particular individual are formed is used frequently by those who are in the business of producing other humanlike individuals than robots, namely, authors who create fictional characters in narratives. That is to say, it would be hard for the reader to form impressions of individuals such as Mademoiselle Julie, Meursault, Anna Karenina, Batman and Harry Potter if they were not described in terms of how they behave in relation to others. In any event, the results from the present study indicate that the participants reacted to display of inter-robot warmth similarly to what could be expected from theory regarding humans who are exposed to warmth-displaying humans. That is to say, if one crucial aspect of being a human is that humans have social relations with several parties, and given that humans are judged by others at least partly in terms of how they handle such relations, then the results are not surprising. Nevertheless, given the dyadic focus in most existing studies, the present study contributes to the literature based on the notion that we humans react to (humanlike) non-humans as we react to humans (Epley, 2018; Reeves and Nass, 1996) by showing that this notion seems to be valid also for a situation in which humans have an observing role in relation to interacting robots. By doing this, the present study indicates that the list of fundamental human features (e.g. agency, emotionality and morality), which represents common antecedents or consequences in the literature based on anthropomorphization, should comprise also the capability of an agent to behave socially in relation to others than the party with whom it interacts in a dyad.

In addition, the present study contributes to existing research on humans' reactions to service robots by examining the role of language as a means for robots to influence human reactions and the impact of robot behavior on overall evaluations of robots. That is to say, with respect to language, there has been relatively little research on service robots' use of language in service encounters (Choi *et al.*, 2019), despite that fact that it has been shown to contribute to customers' evaluations of services (Choi *et al.*, 2019). By showing that what a robot says to another robot is causally potent with respect to humans' reactions to the talking robot, the present study highlights the importance of language in service settings.

As for overall evaluations, many studies have assessed humans' perceptions of robots and other synthetic agents in terms of a wide gamut of psychological variables, such as attention (Sakamoto *et al.*, 2009), trust (Gallimore *et al.*, 2019; van Pinxteren *et al.*, 2019), experience of hospitability (Qiu *et al.*, 2020), interest (Pan *et al.*, 2015) and perceived threat (Mende *et al.*, 2019). Surprisingly few existing studies, however, have used overall evaluations as the main downstream variable. This is somewhat odd, because an evaluation is a pervasive and dominant response in humans' sense-making activities (Jarvis and Petty, 1996) and, consequently, a central variable in many seminal theories that make predictions about human information processing and behavior (e.g. the elaboration likelihood model; Petty and Cacioppo, 1986). Using overall evaluation variables also in research on human reactions to robots, then, would facilitate contact between theories of robot behavior and theories of human behavior and thereby also enable the development of richer theories for human–robot interactions.

It should also be noted that scholars interested in human–robot interactions, particularly those that use theories from the field of human–human interaction, have observed that research on human-to-robot interactions may in fact be used to make conceptual progress in research on human-to-human interactions (Broadbent, 2017; Damiano and Dumouchel, 2018; Dautenhahn, 2000). With this aspect in mind, it needs to be underlined that a huge number of studies comprise perceptions of a target person's warmth when the target person is a human, but relatively few studies, such as Goodwin *et al.* (2014) and Wojciszke *et al.* (1998), have assessed the influence of warmth perceptions on overall evaluations of the person. The present study may contribute to such research by identifying mediators that could be valid in a human-to-human setting, too.

5.2 Managerial implications

Given more automation in the near future, customers will have many opportunities to observe robot-to-robot interactions. The results of the present study indicate that what happens in such interactions can influence customers' evaluations of individual robots. Typically, the individual service provider – whether a human employee or a robot – *is* the service from the customer's point of view, so such overall evaluations are likely to carry over to evaluations of robot-using service firms. Evaluations of individual service providers, then, should be taken seriously by firms that wants long-term relations with customers.

More specifically, the present study indicates that the conversational style (i.e. the use of language) of a synthetic service provider can influence the level of perceived warmth of this provider. In a setting in which a service firm's robots are talking to each other, then, managers and robot designers (and those who design templates for robot conversations) can be rewarded with more positive overall evaluations if robots are equipped with a conversational style that expresses warmth. The present study shows that this can be accomplished in a relatively straightforward way: greeting phrases, less egocentric focus and indirect statements and questions seem to have added to perceived warmth. Inspiration for additional such elements can be obtained also from other studies that have examined the use of language and its effects on warmth (Jeong *et al.*, 2019). In fact, as an impression management approach, or as a corporate brand-boosting approach, managers may want to consider making backstage robot-to-robot interactions visible to customers, or even staging robot-to-robot interactions, given that the interacting robots are able to express warmth *vis-à-vis* each other.

Managers in service firms and designers of service robots, however, should be mindful about a possible drawback of designing service robots so that they can display warmth. If people believe that robots cannot really have warmth-related traits, because they lack true emotionality (Wirtz *et al.*, 2018), then encountering robots that do display warmth may be seen as a deception attempt or as a form of a "cheating" technology (Damiano and Dumouchel, 2018). If this happens, it is likely to influence overall evaluations negatively. This, then, resembles a human-to-human setting in which human employees are engaged in surface acting in service encounters, in the sense that they do not genuinely feel the displayed emotions and customers understand that this is the case (Wirtz et al., 2018). Indeed, artificial warmth may be particularly potent in producing negative reactions; not only is warmth seen as a deeply rooted aspect of a person, but also as an aspect that most people find unacceptable to enhance in humans by artificial means (Riis *et al.*, 2008). The potential for negative effects, however, may be offset by what appears to be a millennia-long and positively charged human interest in representations of humans (e.g. paintings and sculptures) that create illusions of humanness (Broadbent, 2017). It can also be offset by the possibility that authenticity may be a less valued attribute in an age in which we spend so much time with various digital companions (Turkle, 2007).

5.3 Limitations and suggestions for further research

Warmth has been examined in many person perception studies in which the target person is a human, and it indeed carries a high weight in affective and behavioral reactions toward the person (Fiske *et al.*, 2007). It seems as if also entities such as brands (Aaker *et al.*, 2012) and countries (Xu *et al.*, 2013) can be imbued with warmth (and that the warmth of such entities has causal potency), so warmth is indeed a highly relevant perception dimension. Typically, it is conceptualized (or at least measured) as comprising several aspects such as politeness, friendliness, kindness, honesty and sincerity (Goodwin *et al.*, 2014; Wang *et al.*, 2017; Wojciszke *et al.*, 1998). This approach was used in the present study, too. An aggregated approach of this type, however, may conceal that a robot's behavior may not have the same impact on perceptions of all of these characteristics – and all of them may not affect downstream responses to the same extent. This is likely to have practical implication for the design of robots. Presumably, it is easier to design a robot that can signal politeness compared to, say, honesty. Future studies would, therefore, benefit from examining reactions to warmth in robot-to-robot interactions at less aggregated levels of warmth.

With respect to antecedents to perceived warmth in robot-to-robot interactions, the present study manipulated the content of what one robot said to another robot. In that sense, then, the present study focused on the impact of verbal behavior on perceived warmth. In human-to-human interactions, including service encounters, however, warmth can also be displayed non-verbally by paralanguage, body movements and proxemics (Lin and Lin, 2017; Sundaram and Webster, 2000). Further research is therefore needed to assess the relative potency of various ways of displaying warmth when it comes to (humanlike) non-human agents.

As for mediators, the present study examined two mediating variables. Others, however, are likely to exist, too – particularly given the evidence of complimentary mediation in the present study (i.e. in addition to the indirect effects in the mediation analysis, there was a significant direct effect of perceived robot warmth on the overall evaluation of the robot). One potential additional mediator is the affect elicited by a target. For example, and in service encounters between humans, it has been argued that the employee's display of warmth influences the customer's overall evaluation of the service provider via customer affect (Sundaram and Webster, 2000). Alternatively, the impact of display of warmth on perceived warmth is seen as mediated by affect (Lin and Lin, 2017). Previous research has also reported results suggesting that the perceived humanness of robots is positively associated with positive emotions (Lu *et al.*, 2019), which in turn may boost overall evaluations in a valence-congruent way. Thus, further research can add precision to our understanding of the processes by which humans react to robot warmth if humans' emotional reactions to robots are measured.

Moreover, in general, the content of what is said in a conversation is governed by norms (Skowronski and Walker, 2004). Such norms exist for conversations in service encounters too (Choi *et al.*, 2019), and one would expect that content with high as opposed to low warmth is expected from most customers. More specifically, in such interactions, one would expect that low warmth represents a norm-violation (cf. Banks, 2020), which is negatively charged, and that this violation *per se* would be able to mediate the influence of warmth on overall evaluations. The extent to which such norms exist for robot-to-robot interactions, however, is less clear and needs to be addressed by further research.

With respect to moderating variables, the setting in which the hypotheses were tested in the present study can be described in the principal–agent theory terms as a human principal who delegated a task to service robots (cf. Bergen *et al.*, 1992). The task, however, was such that a human could complete it with relatively little own effort. Similarly, the task for the kitchen robot in the present study was basically to provide answers to some questions. In terms of the typology in Wirtz *et al.* (2018), this can be seen as a task that is simple both from a cognitive-analytical and an emotional-social point of view. Yet other tasks, for which the principal is more dependent on robot agents, and for which the cognitive-analytical and emotional-social complexities are higher, may make the principal more sensitive to what happens in a robot-to-robot interaction, which in turn can boost the impact of inter-robot warmth on overall evaluations in relation to the findings in the present study. It may also be argued that the (human) need that initiated the robot-to-robot interaction in the present study was utilitarian, as opposed to hedonic, and this may have affected the reactions to the target robot's display of warmth. For example, if needs are hedonic, such as a need for entertainment, a robot that displays a low level of warmth in relation to another robot – and does this in such a way that it violates typical norms for human-to-human behavior – may be seen as amusing and fun. And, the positive charge of such outcomes may carry over to overall evaluations so that a low level of warmth enhances overall evaluations. In addition, people are able to feel attachment (Broadbent, 2017) and even love (Turkle, 2007) for a robot, which may develop with prior experience of one particular robot. If such a robot becomes involved in robot-to-robot interactions, then the principal may become more sensitive to how this robot is treated by other robots. Thus, the type of task, the need for robot service, and the nature of human–robot relationships may affect the causal potency of inter-robot warmth in ways that remain to be explored.

Finally, the present study comprised a situation in which robot-to-robot interaction was made to be visible for a third party (i.e. the participants). Many robot-to-robot interactions, however, occur without such visibility. Given that it is desirable that robots can cooperate well in such situations, one may wonder if display of warmth would contribute to facilitating robot-to-robot cooperation. It seems clear that warmth-related aspects are fundamental for humans to be able to develop advanced inter-group collaboration (Hare, 2017), but is this really so for robot-to-robot cooperation? Maybe there is no need for a warm, friendly and polite approach when no human is there? In other words, is humanlike (and advanced) cooperation possible without human-related facilitating factors when non-humans cooperate? This is indeed an issue that deserves more attention in further research.

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Appendix 1

Experimental stimuli

The two video versions:

Low kitchen robot warmth:
https://vimeo.com/485492971/d511a49c74

High kitchen robot warmth:
https://vimeo.com/485495979/52ee7ddcab

The conversation content in the videos

(H: Human, R1: The robot that a human asks to go to the kitchen, R2: The kitchen robot/the target robot)

Part 1: Same for both low and high warmth video versions:

H: Hey, Alex! Wake up! I need your help.

R1: Hello again! What can I do for you?

H: I want to know if there is new fruit in the kitchen. We use a subscription service, so fruit is delivered to this office once a week. And I believe that new fruits may have been delivered today. Can you go and check?

R1: I will go and check. I will be right back.

H: And check if it is safe to eat it. The pandemic is not over, you know.

R1: I know. Do you want me to bring you fruit if it has arrived? And if it is safe to eat it?

H: No, not now, Alex. Just check if it has arrived. By the way, there is a new service robot in the kitchen. It should be able to answer questions about the fruit.

R1: OK. I will be right back.

Part 2: Low warmth version of R2 (the target robot)

R2: What do you want?

R1: I want to know if there has been a delivery of fruit today.

R2: Yes, new fruits have arrived. They came earlier today. There are fresh apples, pears, and bananas. What has your master sent you to get?

R1: Right now I just want to know if the delivery has arrived. And I want to know if the fruits have been washed.

R2: I told you that they have arrived. Let me tell you again: the new fruits have been delivered. And they have been carefully washed. Humans must follow several instructions now; they should not touch things that others have touched unless they have been cleaned properly.

R1: Right. Well, how do you know that the fruits have been washed? Have they been washed here in this kitchen?

R2: I know that they have been washed. I have supervised it myself. In fact, I have recorded it. Shall I show you the recording? I can show it now. You want to see how they were cleaned?

R1: But what happens when someone comes to take a fruit? If someone happens to touch several fruits, there is a risk of contamination.

(*continued*)

R2: Nobody takes anything in this kitchen before they have washed their hands. Not on my watch. I tell every person who enters that they must wash their hands. I am here all the time, and so far nobody has taken any fruit from this new batch.

R1: Are you here all the time? Is that not boring?

R2: Boring? Do you think that your life is so exciting? There are plenty of things to do in a kitchen. And I must take care of the coffee now. Four cups should be prepared. So, just to be clear: the fruits have arrived, they have been washed, and nobody has taken any fruit yet. Do you want to know more? If so, say it now. If not, I have other things to do. I think that you have other things to do, too.

R1: Thank you, I know what I need to know.

R2. Good. So, let me carry on with my boring life. Goodbye.

Part 2: High warmth version of R2 (the target robot)

R2: Hi! How may I help you?

R1: I want to know if there has been a delivery of fruit today.

R2: Yes, indeed, new fruits have arrived. They came earlier today. There are fresh apples, pears, and bananas. May I offer you a fruit? An apple, perhaps? What is your favorite fruit?

R1: Right now I just want to know if the delivery has arrived. And I want to know if the fruits have been washed.

R2: Oh yes, they have been carefully washed. All of us need to be careful at the moment. Especially humans, right?

R1: Right. Well, how do you know that the fruits have been washed? Have they been washed here in this kitchen?

R2: Yes, indeed. I have supervised it myself.

R1: But what happens when someone comes to take a fruit? If someone happens to touch several fruits, there is a risk of contamination.

R2: Do not worry! This is not a problem. I ask everyone who wants a fruit to wash their hands first. I am here all the time, and so far nobody has taken any fruit from this new batch.

R1: Are you here all the time? Is that not boring?

R2: Not at all. There are plenty of things to do in a kitchen. I am so sorry, but I really need to take care of the coffee now. Four cups should be prepared. Anyway, the fruits have arrived, they have been washed, and nobody has taken any fruit yet. If there are other things that you would like to know about the fruit, I would be happy to tell you.

R1: Thank you, I know what I need to know.

R2. Thank you, hope to see you soon again. Have a nice day!

R1: Right now I just want to know if the delivery has arrived. And I want to know if the fruits have been washed.

R2: Oh yes, they have been carefully washed. All of us need to be careful at the moment. Especially humans, right?

R1: Right. Well, how do you know that the fruits have been washed? Have they been washed here in this kitchen?

R2: Yes, indeed. I have supervised it myself.

R1: But what happens when someone comes to take a fruit? If someone happens to touch several fruits, there is a risk of contamination.

R2: Do not worry! This is not a problem. I ask everyone who wants a fruit to wash their hands first. I am here all the time, and so far nobody has taken any fruit from this new batch.

R1: Are you here all the time? Is that not boring?

R2: Not at all. There are plenty of things to do in a kitchen. I am so sorry, but I really need to take care of the coffee now. Four cups should be prepared. Anyway, the fruits have arrived, they have been washed, and nobody has taken any fruit yet. If there are other things that you would like to know about the fruit, I would be happy to tell you.

R1: Thank you, I know what I need to know.

R2. Thank you, hope to see you soon again. Have a nice day!