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What's Best for Customers: Empathetic Versus Solution-Oriented Service Robots

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Abstract

A promising application of social robots highlighted by the ongoing labor shortage is to deploy them as service robots at organizational frontlines. As the face of the firms, service robots are expected to provide cognitive and affective supports in response to customer inquiries. However, one question remains unanswered: Would having a robot with a high level of affective support be helpful when such a robot cannot provide a satisfactory level of cognitive support to users? In this study, we aim to address this question by showing that empathetic service robots can be beneficial, although the extent of such benefits depends on the quality of services they provide. Our in-person human–robot interaction study (n = 55) shows that when a service robot can only provide a partial solution, it is preferable for it to express more empathetic behaviors, as users will perceive it to be more useful and will have a better customer experience. However, when a service robot is able to provide a full solution, the level of empathy displayed by it does not result in significant differences on perceived usefulness and customer experience. These findings are further validated in an online experimental study performed in another country (n = 395).

Keywords Service robots · Empathy · Social robotic · Human–robot interaction · Multimodal interaction

1 Introduction

Service robots are "system-based autonomous and adaptable interfaces that interact, communicate, and deliver service to an organization's customers" [1]. These robots are commonly placed at organizational frontlines, where they interact with customers in need of assistance directly. Hence, they are expected to perform similar roles to human employees, that is to provide cognitive and affective supports in response to customer inquiries. Cognitive support focuses on cognitive clarity enhancement, such as question-answering, while affective support focuses on emotional care and comfort [2,3]. Advances in robotics make it possible for these service robots to offer cognitive support approaching similar competence level as human employees. Similarly, social robotics research has made significant progress in developing robots capable of engaging in social interaction to provide emotional support to customers.

One particularly promising approach to enhance a robot's affective capability is by implementing artificial empathy [4]. Empathy is the ability to understand other's emotions and to react appropriately with congruent expressions [5]. Simulating natural and believable empathy in social robots is an open challenge. Thus, empathy shown by service robots is yet to correspond to genuine empathy shown by human employees [1,6–8]. With this in mind, service firms raise some concerns whether such artificial empathy can fulfil customers' need for affective supports necessary for a more holistic and satisfying customer service experience [9–11].

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Prior research has investigated how artificial empathy can be implemented in robots, particularly in socially assistive robots and companion robots [12]. Findings of this stream of research demonstrate that robots can simulate empathy through multimodal interaction, such as using verbal responses, speech prosody, gaze, appearance (e.g., LED displays), facial expression, and body movement [13–18]. Overall, these studies demonstrated that users have a more positive attitude or form a more positive impression towards robots that possess a higher (vs. lower) level of empathy capacity by displaying more (vs. less) empathic expressions. In addition, most studies have focused on the manipulation of empathy capacity whereby researchers aim to formulate the best approach to emulate empathy that is still sufficiently believable from the perspective of users [19]. In such studies, it is often assumed that robots can perform their functional cognitive tasks well. However, depending on the robot, the environment it works in, and the task, this assumption is not always true. This leaves us with an intriguing inquiry, that is: *would having a robot with a high level of empathy capacity (i.e., displaying more empathic expressions) be helpful when such a robot can not fully perform their functional cognitive tasks?*

Focusing on the service robot context, this research therefore aims to investigate whether the effect of a service robot's empathy capacity on its perceived evaluation is dependent on the extent to which a service robot can perform its functional cognitive tasks. As we focus on a service robot, it is reasonable to assume that such a service robot performs its functional cognitive tasks well if it provides the best possible solution to their customers. Specifically, a robot offering full-solutions to its customers is considered as having a better service quality, while a robot offering partial-solutions is considered as having a lower service quality. We conducted two user studies to investigate how a social robot's empathy and the type of solution it provides influences its users' perception towards the robot and their satisfaction towards the services they receive. Expressing empathy is especially important for deflating conflicts, handling difficult requests, and effective interaction with customers who may be experiencing negative feelings [20]. Thus, in this study we design the interaction scenario to be a service robot at a student help desk, whose task is to help a student in distress regarding their submission of a health-related special consideration request on an overdue assignment.

Remainder of this paper is organized as follows: in Sect. 2, we present the theoretical rationale of this study and our hypotheses. To test these hypotheses, we recruited a diverse participant population and conducted two user studies, as detailed in Sect. 3: (1) an in-person human-robot interaction (HRI) study conducted in a robotics lab at an Australian university, and (2) an online video-perception study conducted with UK-based participants. In Sect. 4, we report findings from these experiments. In Sect. 5, we conclude with general discussion on theoretical and managerial implications of our findings, as well as limitations and future directions of this work.

2 Background

2.1 Empathy in Social Robots

Empathy describes alignment of emotions in human interaction, where a person puts themselves in other's perspective and expresses emotions similar to the other's. It is essential to human's affective competence and social-emotional intelligence [21]. Research in social robotics and HRI has demonstrated the benefits of artificial empathy for a robot to interact in a more socially acceptable manner [22]. Better affective competence is closely related to a robot's capability to achieve its intended outcomes and to provide satisfying services. For example, emotional warmth is shown to aid error recovery in service robots [23]. Further, emotional design is increasingly adopted in HRI for better usability [24]. In the retails context, emotionally competent robots were found to be perceived positively by customers [25]. In healthcare applications, empathic robots were shown to offer effective services [26].

Service robots interact directly with customers; hence, they are expected to possess a certain level of social capabilities. Indeed, a more sociable robot is generally preferred over a less sociable one as the social cues embedded in robots elicit perceived social agency, which makes users interactions with these robotic agents closer to human-to-human interactions [14]. As customers approach service robots with various emotional states, one attribute of service robots that is deemed necessary to ensure a positive customer-robot interaction experience is their empathy capacity. Empathy capacity, in our study, is defined as *the ability of service robots to display empathic responses to customers*. While service robots cannot feel empathy genuinely [27], they can be programmed to simulate empathy. Simulating empathy means that the service robots should behave as if their customers' emotions affect them and manifest their emotional responses through their behaviors to align with that emotional context [17]. In this case, service robots feel for or with their customers [6] but there are no expectations to share others' emotional states. Their empathic responses merely intend to signal customers that their feelings are understood by them [13].

Empathy capacity in the context of service robots can indeed be stimulated through anthropomorphic robot design, in particular anthropomorphic behaviour which pertains to the way service robots act and how they express their emotions [28] commonly observed through their verbal and non-verbal communications during their interactions with users [27,29]. Previous research has shown a number of features that can be embodied into robots which can influence users affectively in perceiving robots [30,31]. For instance, through the gestures and body language of robots, human users can derive certain emotions or moods [32]. Voice tone further can contribute to emotional speech of the robot which later influences how users perceive their interaction with robots [33]. Content of conversational script used by a robot can indicate affective response [34]. Head tilt has been found to influence perceived warmth of robots [35]. In addition, a study by Johnson et al (2013) [36] demonstrated that certain eye colors exhibited by robots are associated with particular emotions. To be able to emulate empathy capacity holistically, this experimental study therefore considers a combination of gestures, head tilt, voice tone, verbal content, and eye color of service robots. Focusing on both verbal and non-verbal communication also provides social cues that not only make the customer-robot interaction more personal but also more intuitive and natural [13,37].

2.2 Service Robots

Roboticists have made some progress in developing service robots that enable them to deliver services at the same technical competence level as human employees in mostly predictable situations. However, in deployment, service robots may not always provide complete solutions to customers due to uncertainty and complexity in the environment or variances in individual service scenarios. Service robots are deployed by firms with the assumption that they can solve customers' problems. Prior study in service research has shown that the quality of solutions provided by frontline employees has largely impacted customer satisfaction [38]. Therefore, in this study, type of solutions offered by service robots is introduced as the second factor that can influence customer-service robot interaction which may have spill over effect on perceived service quality.

Drawing upon social support literature (e.g., Folkman et al., 1986 [39]; Schaefer et al., 1981 [40]), we propose two types of solutions that can be offered by service robots: full and partial solutions. As the name implies, service robots provide full solutions when they completely solve the customers' problems. It is similar to what Menon and Dube (2007) [41] referred to as instrumental support as service robots in this situation actively attempt to improve the situation customers experience with the aim to help them in reaching their goals. Hence, customers would exert very minimal effort as they fully rely on service robots to solve their problems. On the other hand, service robots provide partial solutions when they equip customers with some suggestions that customers can later use to solve their problems [42]. Here, customers would still need to exert some effort to solve their problems.

Customers generally approach service robots as they need assistance from these robots to address their inquiries. In response to these, service robots can be programmed to provide either full or partial solutions to customers with either a low or high empathetic response. In this study, we postulate that in the condition where service robots provide full solutions, customers will demonstrate no significant differences on their perceived usefulness towards the robots and overall experience interacting with the robots regardless of the level of empathy capacity shown by the robots. This is because their main goals to interact with the service robots are fulfilled as the robots fully solved their needs. Hence, interacting with a low or a high empathic robot would make no differences at all.

On the other hand, in the condition where service robots provide partial solutions, customers who interact with a more empathetic robot will demonstrate higher level of perceived usefulness towards the robots and a more positive interaction experience than those who interact with a less sympathetic robot. When service robots show high empathy capacity, customers perceive that the robots understand the situations they are experiencing. These robots are then perceived as more caring [43]. Customers thus feel that they receive affective support needed to provide assurance that they can solve their problems using the suggestions the service robots provide them. As such, they would perceive such service robots to be more useful and evaluate their interaction more positively compared to if they interact with service robots that show low empathy capacity. We therefore hypothesize:

- **H1**: Type of solution moderates the relationship between a service robot's empathy capacity and **perceived usefulness**, such that when a service robot provides a partial solution, a high empathetic robot is perceived as more useful than a low empathetic one.
- **H2**: Type of solution moderates the relationship between a service robot's empathy capacity and **service experience**, such that when a service robot provides a partial solution, a high empathetic robot is perceived to provide a more positive service experience than a low empathetic one.

Prior research has shown that users rate their interactions with robots more positively when they perceived robots are more useful [44–48]. We further postulate perceived usefulness as the underlying mechanism between empathy capacity and overall service experience moderated by type of solutions offered by service robots. That is, the difference in a service robot's empathy capacity will cause different perception of its usefulness, which results in different customer experience. Thus, we also hypothesize:

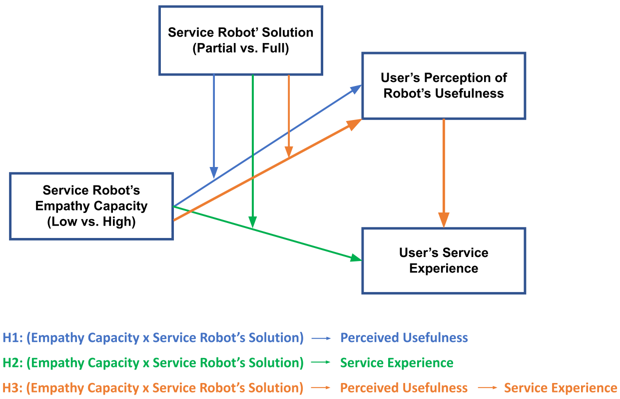


Fig. 1 Conceptual model of our hypotheses

- **H3**: Service robot's solution moderates the **indirect effect** of a service robot's empathy capacity on service experience **via perceived usefulness**.

Note that compared to **H2**, **H3** is aimed at understanding the *mediating role* of perceived usefulness between service robots' empathy capacity and service experience taking into account type of solutions.

Figure 1 below shows our conceptual model that depicts the proposed hypotheses.

3 Methodology

Two scenario-based experiments are conducted to test our hypotheses proposed in Sect. 2. Study 1 is a lab study involving an in-person interaction between participants and the service robot Pepper. It aims to test **H1** and **H2**. Study 2 is an online study which aims to validate the findings of Study 1 and test **H3**. In the online study, participants were exposed to a video showing interactions between a user and the service robot Pepper. Both studies were approved by the Human Ethics Low Risk Review Committee at the University where the project was carried out (ID:27172).

3.1 Pre-test of Study 1

Prior to conducting the main study, we conducted a pre-test to select the best stimuli to represent a low (vs. high) empathy capacity service robot, as elaborated below.

We utilized the Pepper robot in our experiment. The Pepper robot, by SoftBank Robotics, was released in 2014 and is one of the most popular service robots on the market [49]. To test our hypotheses about the effect of empathy capacity on the users' experience in interaction with the robot, the default voice of Pepper is replaced with (i) an empathic and (ii) a neutral voice. The text to speech Microsoft Azure Audio Content Creation online open-source platform, which offers a selection of voice inflictions, is deployed to generate the two empathy conditions based on the interaction scenario. Movements of the robot and the color of its eye LEDs are coded directly on the Pepper humanoid robot.

3.1.1 Method and Procedure

We recruited 120 US participants from Amazon Mechanical Turk (MTurk) (Average Age M_{age} = 46.5 years, Standard Deviation SD = 13.5, 59.2% male, 40.8% female). Participants were asked to read a scenario whereby a University student called Sam is unable to complete their assessment on time and needs to apply for a special consideration to avoid a penalty. They were informed that the University is recently deploying a service robot to assist their students. They were then randomly assigned to one of the three videos showing a service robot interacting with the student with different levels of empathy capacity. However, as our pre-test aims to select the best videos to represent low and high levels of empathy capacity, the videos will not include the part where the service robot offers solutions to the students.

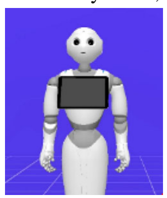
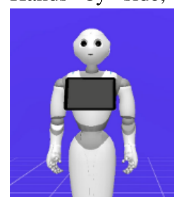
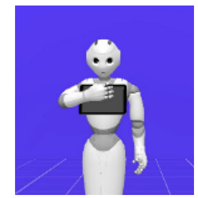
Following prior literature, in this study, empathy capacity of service robots is portrayed from four attributes: gestures, eye-color, voice style, and script language. Stimulus #1 shows a static Pepper robot talking with a standard pitch and a neutral script with the same eye color during an interaction. Stimulus #2 is similar to stimulus #1 but the Pepper robot talks with an empathic script during an interaction. Stimulus #3 depicts a dynamic Pepper robot which can move its hand and tilt its head. It also talks with an emotional pitch and an empathic script with changing eye colors during its interaction. Blue colored eyes were chosen when the Pepper robot acknowledges the negative emotion shared by the student [36]. We expected stimuli #1, #2, and #3 to evoke low, medium, and high empathy capacity respectively. They were then asked to complete a set of empathy capacity-related and perceived efficacy items, followed by demographic questions. Participants were paid US $0.75 for their participation. All participants provided their consent when participating the study. Table 1 describes the three stimuli in details.

3.1.2 Measures

Participants were asked to indicate their agreement to three items measuring empathy capacity adapted from Charrier et al. (2019)[50]: this service robot cared about [the student]'s feelings, this service robot seemed to feel bad about [the student]'s current situation, this service robot comforted [the student] when [the student] felt anxious [50] (M = 4.60, SD = 1.04, α = 0.85).

They were also asked to rate their perceived efficacy in interacting with a service robot using five items adapted from

Table 1 Stimuli for Pre-test

	Stimulus #1 Low empathy capacity	Stimulus #2 Medium empathy capacity	Stimulus #3 High empathy capacity
Gestures	Hands by side, looking straight ahead (static). 	Hands by side, looking straight ahead (static). 	Hand on heart and slow nodding (dynamic). 
Eye LEDs	White (standard).	White (standard).	Changing blue colors/blue tears to show empathy towards the situation experienced by the participant.
Voice style	ArialNeural - with all default for other settings (standard).	ArialNeural - with all default for other settings (standard).	ArialNeural - empathic - with slowed rate on certain words to show empathy towards the situation experienced by the participant.
Conver-sation style	Low empathic script as shown in a conversation that depicts a low affective support. Cognitive support is the same for all conditions. Please see script below.	High empathic script as shown in a conversation that depicts a high affective support, Cognitive support is the same for all conditions. Please see script below.	High empathic script as shown in a conversation that depicts a high affective support. Cognitive support is the same for all conditions. Please see script below.
Script	**Hi Sam, I'm sorry to hear this [low affective support].** But don't worry, illness is one of the eligibility criteria for applying for special consideration. I can help you to submit the application now, if you wish. Would you like to do that? [cognitive support]	**Hi Sam, I'm sorry to hear this, how horrible for you. I realize this must be very hard. I can understand how you feel, and I can imagine you have been anxious for a while now [high affective support].** But don't worry, illness is one of the eligibility criteria for applying for special consideration. I can help you to submit the application now, if you wish. Would you like to do that? [cognitive support]	**Hi Sam, I'm sorry to hear this, how horrible for you. I realize this must be very hard. I can understand how you feel, and I can imagine you have been anxious for a while now [high affective support].** But don't worry, illness is one of the eligibility criteria for applying for special consideration. I can help you to submit the application now, if you wish. Would you like to do that? [cognitive support]

Turja, Rantanen, and Oksanen (2019) [51] (M = 5.57, SD = 0.96, $\alpha = 0.89$). Prior research has shown that technology self-efficacy has an impact on attitude towards technology [52]. This self-efficacy measure was therefore used as our control variable.

All items were measured using a seven-point Likert-type scale (1 = "Strongly Disagree", 7 = "Strongly Agree").

3.2 Study 1

Here we describe Study 1, which is an in-person HRI study with Wizard-of-Oz controlled robot.

3.2.1 Method and Procedure

A laboratory experiment was conducted with 55 participants (M_{age} = 22.4, SD = 3.15; 40% male, 60% female) recruited through flyers distributed around a large public university in Australia. To be eligible to participate, participants should be at least 18 years old and were students at the University. All participations were voluntary. All participants provided their consent when participating the study. This lab study utilized a 2 (empathy capacity: low vs. high) x 2 (type of solution: partial vs. full) between-subjects experimental design.

When participants arrived at the lab, they were asked to read an explanatory statement describing what the study involves and sign a consent form if they agreed to all terms and conditions. Participants were then asked to imagine themselves in a situation whereby they cannot submit their assessment on time and need to apply for a special consideration. A service robot recently deployed by the University would assist them. Participants were required to interact with Pepper the service robot. However, each participant was randomly allocated to one of the four possible conditions (see Table 2). The experiment was conducted using the Wizard of Oz approach, i.e. the experimenter was in full charge of selecting the robot responses and reactions based on the interaction. After completing the interaction session with the service robot, they were then asked to complete a questionnaire.

3.2.2 Measures

Perceived usefulness was measured by four Likert-type items adapted from McGovern, Lambert, and Verrecchia (2019) [53] (1 = strongly disagree, 5 = strongly agree; M = 3.76, SD = 1.05, α = 0.92). Service experience was measured by four five-point bipolar items adapted from Mikolon et al (2015) [54] (M = 4.22, SD = 0.69, α = 0.78). The same self-efficacy measure [51] as in the pre-test was used as our control variable (1 = strongly disagree, 5 = strongly agree; M = 4.53, SD = 0.54, α = 0.75). Table 3 lists all the items used in this study.

3.3 Study 2

Here we describe Study 2, which is an online HRI video perception study.

3.3.1 Method and Procedure

We recruited 400 participants from Prolific, a UK-based consumer research panel. We sent an invitation to participate in this study only to those who are at least 18 years old and registered in the panel as university students. All participants provided their consent when participating the study. Five participants failed an attention check resulting in a usable 395 responses for our main analysis (M_{age} = 23.1, SD = 6.82; 29% male, 71% female). This online study utilized a 2 (empathy capacity: low vs. high) x 2 (type of solution: partial vs. full) between-subjects experimental design.

When participants arrived at the survey site, they were asked to read an explanatory statement describing what the study involves and sign an online consent form if they agreed to all terms and conditions. Participants were then asked to read a scenario about a university student called James who cannot submit his assessment on time and need to apply for a special consideration. A service robot recently deployed by the University would assist him. Participants were required to watch a video showing an interaction between James and Pepper the service robot. However, each participant was randomly allocated to one of the four possible conditions (see Table 4). After viewing the video, they were then asked to imagine they were James when completing the questionnaire.

3.3.2 Measures

Study 2 measured the same items as in Study 1 (see Table 3), namely perceived usefulness [53] (1 = strongly disagree, 5 = strongly agree; M = 3.62, SD = 1.08, α = 0.92), service experience [54] (M = 4.26, SD = 0.70, α = 0.83), and self-efficacy [51] was a control variable (1 = strongly disagree, 5 = strongly agree; M = 4.09, SD = 0.67, α = 0.82).

4 Results

Here we discuss the results of the pre-test, Study 1, and Study 2 in relation to our hypotheses.

4.1 Pre-test of Study 1

Analysis of covariance (ANCOVA) revealed that participants reported significantly different levels of empathy capacity for the three stimuli ($F(2, 116) = 12.67$, $p < .001$). Pairwise comparisons indicated that the mean score for stimulus #3 (M = 5.19, SD = 1.00) was significantly different from stim-

Table 2 Stimuli for Study 1

Context	
Imagine you are a first-year student at Monash University. You have been working on your major assignment. However, on the final submission day, you got very sick and were not able to complete it. To avoid a late submission penalty, you need to apply for special consideration. You have never applied for special consideration before. Also, there is a new special consideration process that students have to follow. You need to submit the application as soon as possible to avoid losing marks that can significantly influence your GPA. Hence, you go to the student service center to find out more.	
You now arrive at the student service center.	
A service robot occupies the service desk, and will be helping you today.	
Low empathy capacity	High empathy capacity
Stimulus#2 from the pre-test	Stimulus#3 from the pre-test
Partial solution	Full solution
To apply for special consideration, all you need to do is go to this website to submit an application. Please take a note and do this in your own time. Please make sure you read the eligibility criteria to make the application successful.	We can complete the application form together right now on my tablet. You will need to fill out the form by putting in your participant number, and the reason you are applying for special consideration. You will receive an email within 24 hours of filling out this form to update you on the progress of your application.
[Pepper only shows the website link on its tablet]	[Pepper shows a form in which participants complete together with Pepper and at the end participants can submit the form for approval]

Table 3 Scale and items used in Study 1 and Study 2

Constructs and their respective items
Perceived usefulness
Using the service robot “Pepper” to apply for special consideration saved me time
The service robot ‘Pepper” made it easier for me to apply for special consideration
The service robot enhanced the effectiveness in applying for special consideration
The service robot was useful in helping me to apply for special consideration
Service experience
How would you rate your overall service experience in using the service robot “Pepper” to apply for special consideration?
Complex[1] - Simple
Negative - Positive
Bad - Good
Unfavorable - Favorable
Perceived self-efficacy
Generally speaking, I consider myself technologically competent.
I am confident in my ability to learn how to use a service robot if I had to.
I believe it would be easy for me to learn how to use a service robot if it was going to be used in my industry in the future.
I am confident in my ability to learn simple programming of service robots if I were provided the necessary training.
I am confident in my ability to learn how to use service robots in order to guide others to do the same.

[1]“Complex” is the original item adopted from Mikolon et al (2015) [54]. In this context, it refers to how complicated the overall service experience in using a service robot is

Table 4 Stimuli for Study 2

Context
Please read and imagine the scenario below.
James, a University student, has been working on his major assignment. However, on the final submission day, James got very sick and was unable to complete it. James has a medical certificate with him to prove his illness. To avoid a late submission penalty, he needs to apply for special consideration. He has never applied for special consideration before. Hence, James goes to the University's student service center to find out more about the special consideration application procedure.
James is now at the University' student service center. Apparently, a service robot occupies this center.
Watch and listen to James' interaction with the service robot by playing these videos.
Participants are then randomly allocated to one of the four conditions.
Video (full interaction scripts)
Low empathy capacity - partial solution
https://www.youtube.com/watch?v=KSxG1oKLLjY
https://www.youtube.com/watch?v=tVKQMxa14kI
Low empathy capacity - full solution
https://www.youtube.com/watch?v=KSxG1oKLLjY
https://www.youtube.com/watch?v=FacFv1Dxt6E
High empathy capacity - partial solution
https://www.youtube.com/watch?v=7KQDZ3SoSNs
https://www.youtube.com/watch?v=FWEBpTb3yUU
High empathy capacity - full solution
https://www.youtube.com/watch?v=7KQDZ3SoSNs
https://www.youtube.com/watch?v=blWiUQAtUO4

ulus #1 (M = 4.19, SD = 0.92) and stimulus #2 (M = 4.43, SD = 0.91). However, stimulus #1 was not significantly different from stimulus #2. Self-efficacy exerted no significant influences as a control variable.

Taken together, these results suggest that participants perceived the service robots in stimulus #1 and stimulus #2 evoke similar level of empathy capacity. Considering in the stimulus #2, the Pepper robot talks with an empathetic script during an interaction but still was perceived as similar in the empathy capacity level as in the stimulus #1, we believe stimulus #2 is better in representing a low empathy capacity service robot. Hence, in the main study, we used stimulus #2 to represent a low empathy capacity service robot and stimulus #3 to represent a high empathy capacity service robot.

4.2 Study 1

Our in-person HRI experiments in Study 1 provide support for **H1** and **H2**, as detailed below.

4.2.1 Manipulation Check

We asked participants to indicate whether the service robot helps them in filling out and submitting the special consideration form (two options: Yes or No). Participants in the full solution condition were more likely to choose the "Yes" option (89.3% vs. 10.7%; $\chi^2(1) = 44.19$, $p < .001$). In addition, participants in the partial solution condition all chose the "No" option.

It can be observed that there exist inconsistencies in how participants, particularly in the full solution condition, answered this question. It may be due to how they interpreted the help action of the service robot in that they perceived that the service robot still did not assist them fully as during their interactions they were still required to input a few information on their own. Nevertheless, this result principally confirms our solution type manipulation. Since removing less compliant participants (n=3) did not result in meaningful changes, we present our results with all participants included.

4.2.2 Hypothesis Testing

A two-way analysis of covariance revealed a non-significant main effect of empathy capacity ($F(1, 50) = 0.20$, $p = 0.65$) and a significant main effect of solution type ($F(1, 50) = 10.97$, $p = 0.002$). A significant interaction effect of empathy capacity and solution type on perceived usefulness ($F(1, 50) = 5.80$, $p = 0.02$) was also revealed. Participants who were provided with full solution exhibited a similar level of perceived usefulness regardless of empathy capacity level ($M_{LowEmpathy} = 4.44$, $M_{HighEmpathy} = 3.93$, $p = 0.17$), while those who were provided with partial solution experienced a significantly higher level of perceived usefulness when the service robot showed a high empathy capacity than low empathy capacity ($M_{LowEmpathy} = 2.94$, $M_{HighEmpathy} = 3.69$, $p = 0.05$), providing support for **H1**. Self-efficacy was not a significant control variable ($p = .43$).

A two-way analysis of covariance revealed a non-significant main effect of empathy capacity ($F(1, 50) = 1.31$, $p = 0.26$) and a significant main effect of solution type ($F(1, 50) = 8.58$, $p = 0.005$). It was also revealed that there is a significant interaction effect of empathy capacity and solution type on service experience ($F(1, 50) = 8.23$, $p = 0.006$). Participants who were provided with full solution exhibited a similar level of service experience regardless of empathy capacity level ($M_{LowEmpathy} = 3.83$, $M_{HighEmpathy} = 3.62$, $p = 0.23$), while those who were provided with partial solution experienced a significantly higher level of service experience when the service robot showed a high empathy capacity than low empathy capacity ($M_{LowEmpathy} = 3.12$, $M_{HighEmpathy} = 3.61$, $p = 0.007$), providing support for **H2**. Self-efficacy was not a significant control variable ($p = .09$).

4.2.3 Study 1 Discussion

The findings provide support for **H1** and **H2**, affirming that type of solution (partial vs. full) plays a role in participants' assessment of perceived usefulness and service quality of a low (vs. high) empathetic service robot. In particular, when the service robot is perceived to provide a lower level of empathy capacity during an interaction with a user, the service robot needs to provide full solution to the user to be perceived in a more positive way.

Study 1 was conducted in a lab setting with a relatively small sample size. We would like to validate these findings and therefore conducted our Study 2 in an online environment that allows us to recruit more participants. Another aim of Study 2 is to investigate whether perceived usefulness acts as the underlying mechanism between empathy capacity and service experience moderated by type of solution.

4.3 Study 2

Our online experiments in Study 2 validate findings in Study 1 and provide support for **H3**.

4.3.1 Manipulation Check

As discussed in Study 1, we reworded our manipulation check item. We asked participants to indicate whether (1) the service robot they interacted with completed and submitted the special consideration application for them or (2) the service robot showed them where to find the special consideration application information and they have to submit the form themselves.

Participants in the full solution condition were more likely to choose the first option (92.5% vs. 7.5%; $\chi^2(1) = 319.91$, $p < .001$). In addition, participants in the partial solution condition were more likely to choose the second option (97.4% vs. 2.6%; $\chi^2(1) = 319.91$, $p < .001$). This principally confirms our solution type manipulation. Similar to Study 1, since removing less compliant participants (n=20) did not result in meaningful changes, we present our results with all participants included.

4.3.2 Hypothesis Testing

A two-way analysis of covariance revealed a non-significant main effect of empathy capacity ($F(1, 390) = 0.89$, $p = 0.35$) and a significant main effect of solution type ($F(1, 390) = 160.03$, $p < .001$). It was also revealed a significant interaction effect of empathy capacity and solution type on perceived usefulness ($F(1, 390) = 10.09$, $p = 0.002$). Participants who were provided with full solution exhibited a similar level of perceived usefulness regardless of empathy capacity level ($M_{LowEmpathy} = 4.27$, $M_{HighEmpathy} = 4.13$, $p = 0.11$), while those who were provided with partial solution experienced a significantly higher level of perceived usefulness when the service robot provided high rather than low empathy capacity ($M_{LowEmpathy} = 2.85$, $M_{HighEmpathy} = 3.20$, $p < .05$), providing support for **H1**. Self-efficacy was a significant control variable ($p < .001$).

A two-way analysis of covariance revealed a non-significant main effect of empathy capacity ($F(1, 390) = 0.54$, $p = 0.46$) and a significant main effect of solution type ($F(1, 390) = 23.02$, $p < .001$). It was also revealed that there is a significant interaction effect of empathy capacity and solution type on service experience ($F(1, 390) = 4.49$, $p = 0.04$). Participants who were provided with full solution exhibited a similar level of service experience regardless of empathy capacity level ($M_{LowEmpathy} = 4.46$, $M_{HighEmpathy} = 4.43$, $p = 0.32$), while those who were provided with partial solution experienced a significantly higher level of service experience when the service robot provided high empathy capacity rather than low empathy capacity ($M_{LowEmpathy} = 4.00$, $M_{HighEmpathy} = 4.17$, $p = .05$), providing support for **H2**. Self-efficacy was a significant control variable ($p < .001$).

To test **H3**, considering the control variable, we performed a moderated mediation analysis (PROCESS Model 8 [55]) using 10,000 bootstraps. With service experience as the dependent variable, we found that the index for moderated mediation with perceived usefulness as the mediator is significant (index = -.19, 95% CI [-.32, -.07]). The conditional indirect effect for the partial solution condition is significant ($\beta = 0.12$, 95% CI [.03, .23]), whereas the conditional indirect effect for the full solution condition is not significant ($\beta = -.07$, 95% CI [-.14, .00]). **H3** is therefore supported.

4.3.3 Study 2 Discussion

Using an online experiment with a larger sample size, we not only replicated our findings in Study 1 but also showed the role of solution type as a moderator in a mediating effect of perceived usefulness between service robot's empathy capacity and service experience. In particular, if a service robot is not able to fulfil the user's request completely, having a robot that displays a higher (vs. lower) level of empathy capacity can lead to a higher perceived usefulness of the service robot, which subsequently promotes a more positive service experience.

While the online study setting allows us to further investigate our hypotheses with a larger number of participants from another country, it is worth noting that participants in Study 2 were passive observers of the interactions, compared to participants in Study 1 who were actively interacting with the robot. Thus, observation in Study 2 approximates how service robots may be perceived in deployment. Direct interaction with a robot in general elicits stronger responses compared to indirect observations, which is due to the significant influences co-presence and embodiment has on people's perception [56]. However, video-based studies were shown to be effective in eliciting comparable behaviors [57] and perceptions [58] in remote participants, while being more cost-effective than in-person HRI studies and allowing data collection from a larger number of participants. The remote HRI methodology is particularly useful considering accessibility constraints, such as imposed by the COVID pandemic [59].

5 Discussion and Implications

5.1 Conclusions

Overall, through one lab study and one online experimental study, we contribute to the human-robot interaction research particularly within the service robot context in several ways. First, we provide additional insights by showing that a positive interaction between user and robot in the service context is not solely dependent on service robots' high empathy expressivity level. The type of solutions offered by service robots can serve as the boundary condition, as shown by our findings in both studies. In particular, a service robot displaying more empathic behaviors is necessary when service robots are programmed to still require customers to put their own effort to address their problems. This finding could be interpreted in such a way that users still perceive service robots as smart machines whereby high functionality is preferred to high (artificial) empathy. That is, the users prioritize the service outcomes over the social-emotional interaction experience when being served by a social robot.

Second, we further demonstrate that perceived usefulness is the underlying mechanism responsible for the interaction effect of empathy expressivity level provided by service robots and type of solutions on service quality. We found that there exist differences in usefulness perception of service robots in that service robots are perceived to be more useful in the situation where they provide partial solutions but show high (versus low) empathic response to their users, which later lead to a more positive evaluation of service quality. Considering that in the real-world, deployment of service robots that provide full and error-free solutions are often difficult to achieve, either due to technical limits of the robots or the complexity of the task context, our findings suggest that incorporating empathic displays in service robots benefits the users' experiences and their perception towards the robots.

5.2 Managerial Implications

Service firms eager to adopt service robots into their service establishment would find our findings insightful. First, our findings suggest that a service robot that can fully address customer inquiries (i.e., providing full solutions to customers) is perceived as more useful and therefore positively evaluated in terms of their service quality compared to the one that just partially addresses customer inquiries (i.e., requiring customers to partly solve their problems) regardless of their empathy displays. Such findings suggest that in the situation where service firms are not financially able to acquire more advanced service robots—the ones that can be more sophisticatedly programmed to elicit empathy—service firms have to ensure that service robots can fully solve inquiries raised by customers. However, providing a full solution can be computationally costly compared to implementing partial empathic expressions in the robot's behaviors. In the likely situation where a service robot can only partially address customer inquiries, our findings suggest that a robot's perceived usefulness can be improved when such a robot provides greater (versus less) empathy expressivity to customers.

With the current state of the art in robotics and artificial intelligence, robots are unable to provide a full solution to many problems, especially in unconstrained / unpredictable interactions happening in robot deployment in-the-wild. Thus, enabling service robots with empathic displays is beneficial as it can help mitigate service failures and the robot's limitation in providing partial solutions. This aligns with prior research that found customers are more forgiving towards service failure made by human-like robots [23,60].

However, developing empathic robot behaviors is an open challenge in social robotics as it requires accurate emotion recognition, personalized user modeling, and generation of natural and appropriate emotional expressions. A service robot may misinterpret a person's emotional states and thus have its empathic displays being perceived as inappropriate by the customers, resulting in negative impacts on their experience. Further, as a robot can only simulate empathy, its behaviors can be perceived as deception by the customers or as a lack of effort by the service firms in providing genuine empathic services by human staff. Therefore, it is important to incorporate transparency and explainability in a social robot's service solutions and empathic behaviors in the future, especially for in-the-wild human-robot interactions where erroneous robot behaviors and imperfect service solutions are likely to occur.

5.3 Limitations and Future Research

In this study, we measured individuals' overall perception towards service robot's empathy capacity without differentiating whether the empathy display of such a robot is perceived as genuine or artificial. Future research may thus explore the effect of genuine vs. artificial empathy display of a service robot on perceived usefulness and service experience. This study mainly used one customer service context related to the higher education sector. To further validate our findings, researchers are encouraged to replicate our study in different customer service contexts pertaining to retail and hospitality sectors whereby service robots are also commonly deployed to serve customers. Further, our experiments were conducted in lab settings with simulated service interactions, which can limit the applicability of our findings for service robots interacting with actual customers in real-world deployments. Thus, in the future we plan to replicate this study under real-life service scenarios by adopting the robot in day-to-day operations of the student service center at the university. In addition, our findings along with the practical implications need to be carefully interpreted as in-person studies with a larger sample size may be required to further confirm them.

Our research participants were only exposed to interaction with the service robot once to then determine the perceived usefulness of the service robot and the service quality it provides. While in general customers do not need to establish long-term relationships with organizational frontlines, there are some situations where customers visit service establishments relatively often, for example, when they become regular clients of fitness centers or health care centers. Prior research has found that utilizing empathic robots leads to positive impacts in long term interactions between the users and robots [61]; hence, future research may consider running a longitudinal study to explore whether our findings are still valid for frequent usage contexts.

To control for the uncanny valley effect, this study solely utilizes the humanoid Pepper robot for manipulating the service robot's level of empathy displays. However, as users generally anthropomorphize physical embodiments of robots differently [62], future research may consider varying physical embodiments of service robots (e.g., humanoid versus android service robots) as an additional manipulated factor in our experimental design. Such extension of this study could provide additional insights for firms who are at the stage of considering the physical embodiment types of service robots they should adopt into their service establishments.

Finally, our study was designed such that the service robot recognizes the anxiety felt by its users when providing either partial and full solutions to them. Tsiourti et al. (2019) [18] discovered that a robot that cannot recognize the right emotions felt by its users is perceived more negatively. Future research could then extend our study by investigating the interaction between incongruence on emotion recognition and type of solutions provided by the service robot. It will be intriguing to know whether the negative effect of incongruence on emotion recognition remains if the robot actually fully solves the problems raised by the users.

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Data Availibility Statement The datasets generated during and / or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical Approval The questionnaire and methodology for this study was approved by Human Ethics Low Risk Review Committee at Monash University where the project was carried out (Ethics Approval Number: 27172).

Inflormed Consent Informed consent was obtained from all individual participants included in the study.

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References

1. Wirtz J, Patterson PG, Kunz WH, et al (2018) Brave new world: service robots in the frontline. J Serv Manag
2. Pauw LS, Sauter DA, Van Kleef GA et al (2018) Sense or sensibility? social sharers' evaluations of socio-affective vs. cognitive support in response to negative emotions. Cognit Emotion 32(6):1247–1264
3. Rimé B (2009) Emotion elicits the social sharing of emotion: theory and empirical review. Emot Rev 1(1):60–85
4. Paiva A, Leite I, Boukricha H et al (2017) Empathy in virtual agents and robots: a survey. ACM Trans Interact Intell Syst (TiiS) 7(3):1–40
5. Hoffman ML (2001) Empathy and moral development: implications for caring and justice. Cambridge University Press, Cambridge
6. Decety J, Cacioppo JT (2011) The social neuroscience of empathy. In: The Oxford handbook of social neuroscience. Oxford University Press, p 551–564
7. Davenport T, Guha A, Grewal D et al (2020) How artificial intelligence will change the future of marketing. J Acad Mark Sci 48(1):24–42
8. Milman A, Tasci A, Zhang TC (2020) Perceived robotic server qualities and functions explaining customer loyalty in the theme park context. Int J Contemp Hospit Manag
9. Hennig-Thurau T, Groth M, Paul M et al (2006) Are all smiles created equal? how emotional contagion and emotional labor affect service relationships. J Mark 70(3):58–73
10. Giebelhausen M, Robinson SG, Sirianni NJ et al (2014) Touch versus tech: when technology functions as a barrier or a benefit to service encounters. J Mark 78(4):113–124
11. Gremler DD, Gwinner KP (2008) Rapport-building behaviors used by retail employees. J Retail 84(3):308–324
12. Broekens J, Heerink M, Rosendal H et al (2009) Assistive social robots in elderly care: a review. Gerontechnology 8(2):94–103
13. De Carolis BN, Ferilli S, Palestra G, et al (2015) Towards an empathic social robot for ambient assisted living. In: ESSEM AAMAS, pp 19–34
14. Ghazali AS, Ham J, Barakova E et al (2018) The influence of social cues in persuasive social robots on psychological reactance and compliance. Comput Hum Behav 87:58–65
15. Obaid M, Aylett R, Barendregt W et al (2018) Endowing a robotic tutor with empathic qualities: design and pilot evaluation. Int J Humanoid Rob 15(06):1850,025
16. Lv X, Yang Y, Qin D et al (2022) Artificial intelligence service recovery: the role of empathic response in hospitality customers' continuous usage intention. Comput Hum Behav 126(106):993
17. Tapus A, Mataric MJ (2007) Emulating empathy in socially assistive robotics. In: AAAI spring symposium: multidisciplinary collaboration for socially assistive robotics, pp 93–96
18. Tsiourti C, Weiss A, Wac K et al (2019) Multimodal integration of emotional signals from voice, body, and context: effects of (in) congruence on emotion recognition and attitudes towards robots. Int J Soc Robot 11(4):555–573
19. Leite I, Pereira A, Mascarenhas S et al (2013) The influence of empathy in human-robot relations. Int J Hum Comput Stud 71(3):250–260
20. Kokko T, Mäki M (2009) The verbal judo approach in demanding customer encounters. Serv Mark Q 30(3):212–233
21. Decety J, Jackson PL (2004) The functional architecture of human empathy. Behav Cogn Neurosci Rev 3(2):71–100
22. Tian L, Oviatt S (2021) A taxonomy of social errors in human-robot interaction. ACM Trans Hum Robot Interact (THRI) 10(2):1–32
23. Choi S, Mattila AS, Bolton LE (2021) To err is human (-oid): how do consumers react to robot service failure and recovery? J Serv Res 24(3):354–371
24. Saraiva M, Ayanoğlu H, Özcan B (2019) Emotional design and human-robot interaction. In: Emotional design in human-robot interaction. Springer, p 119–141
25. Song CS, Kim YK (2022) The role of the human-robot interaction in consumers' acceptance of humanoid retail service robots. J Bus Res 146:489–503
26. Lisetti C, Amini R, Yasavur U et al (2013) I can help you change! an empathic virtual agent delivers behavior change health interventions. ACM Trans Manag Inf Syst (TMIS) 4(4):1–28
27. Sim DYY, Loo CK (2015) Extensive assessment and evaluation methodologies on assistive social robots for modelling human-robot interaction-a review. Inf Sci 301:305–344
28. DiSalvo C, Gemperle F, Forlizzi J (2005) Imitating the human form: four kinds of anthropomorphic form. Unpublished manuscript Accessed April
29. Moshkina L, Trickett S, Trafton JG (2014) Social engagement in public places: a tale of one robot. In: Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction, pp 382–389
30. McCartney G, McCartney A (2020) Rise of the machines: towards a conceptual service-robot research framework for the hospitality and tourism industry. Int J Contemp Hospital Manag
31. Tung VWS, Au N (2018) Exploring customer experiences with robotics in hospitality. Int J Contemp Hospital Manag
32. Beck A, Hiolle A, Mazel A, et al (2010) Interpretation of emotional body language displayed by robots. In: Proceedings of the 3rd international workshop on affective interaction in natural environments, pp 37–42
33. Tamagawa R, Watson CI, Kuo IH et al (2011) The effects of synthesized voice accents on user perceptions of robots. Int J Soc Robot 3(3):253–262
34. Choi S, Liu SQ, Mattila AS (2019) "How may i help you?" says a robot: examining language styles in the service encounter. Int J Hosp Manag 82:32–38
35. Mara M, Appel M (2015) Effects of lateral head tilt on user perceptions of humanoid and android robots. Comput Hum Behav 44:326–334
36. Johnson DO, Cuijpers RH, van der Pol D (2013) Imitating human emotions with artificial facial expressions. Int J Soc Robot 5(4):503–513
37. Feng B, Li S, Li N (2016) Is a profile worth a thousand words? how online support-seeker's profile features may influence the quality of received support messages. Commun Res 43(2):253–276
38. Li F, Lu H, Hou M et al (2021) Customer satisfaction with bank services: the role of cloud services, security, e-learning and service quality. Technol Soc 64(101):487
39. Folkman S, Lazarus RS, Dunkel-Schetter C et al (1986) Dynamics of a stressful encounter: cognitive appraisal, coping, and encounter outcomes. J Pers Soc Psychol 50(5):992
40. Schaefer C, Coyne JC, Lazarus RS (1981) The health-related functions of social support. J Behav Med 4(4):381–406
41. Menon K, Dubé L (2007) The effect of emotional provider support on angry versus anxious consumers. Int J Res Mark 24(3):268–275
42. Magnini VP (2009) Understanding and reducing work-family conflict in the hospitality industry. J Hum Res Hospital Tour 8(2):119–136
43. Brave S, Nass C, Hutchinson K (2005) Computers that care: investigating the effects of orientation of emotion exhibited by an embodied computer agent. Int J Hum Comput Stud 62(2):161–178

44. Abou-Shouk M, Gad HE, Abdelhakim A (2021) Exploring customers' attitudes to the adoption of robots in tourism and hospitality. J Hospital Tour Technol
45. Fuentes-Moraleda L, Diaz-Perez P, Orea-Giner A et al (2020) Interaction between hotel service robots and humans: a hotel-specific service robot acceptance model (sRAM). Tour Manag Perspect 36(100):751
46. Lee WH, Lin CW, Shih KH (2018) A technology acceptance model for the perception of restaurant service robots for trust, interactivity, and output quality. Int J Mobile Commun 16(4):361–376
47. Lu L, Cai R, Gursoy D (2019) Developing and validating a service robot integration willingness scale. Int J Hosp Manag 80:36–51
48. Turja T, Aaltonen I, Taipale S et al (2020) Robot acceptance model for care (RAM-care): a principled approach to the intention to use care robots. Inf Manag 57(5):103,220
49. Collins GR (2020) Improving human–robot interactions in hospitality settings. Int Hospital Rev
50. Charrier L, Rieger A, Galdeano A, et al (2019) The rope scale: a measure of how empathic a robot is perceived. In: 2019 14th ACM/IEEE international conference on human-robot interaction (HRI), IEEE, pp 656–657
51. Turja T, Rantanen T, Oksanen A (2019) Robot use self-efficacy in healthcare work (RUSH): development and validation of a new measure. AI Soc 34(1):137–143
52. Dabholkar PA, Bagozzi RP (2002) An attitudinal model of technology-based self-service: moderating effects of consumer traits and situational factors. J Acad Mark Sci 30(3):184–201
53. McGovern P, Lambert J, Verrecchia M (2019) Mobile banking adoption: an exploration of the behavioural intention of consumers in Ireland. J Acc Financ 19(8):2158–3625
54. Mikolon S, Kolberg A, Haumann T et al (2015) The complex role of complexity: how service providers can mitigate negative effects of perceived service complexity when selling professional services. J Serv Res 18(4):513–528
55. Hayes AF (2017) Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. Guilford publications, New York
56. Biocca F, Harms C, Burgoon JK (2003) Toward a more robust theory and measure of social presence: review and suggested criteria. Presence Teleoperat virt Environ 12(5):456–480
57. Honig S, Oron-Gilad T (2020) Comparing laboratory user studies and video-enhanced web surveys for eliciting user gestures in human-robot interactions. In: Companion of the 2020 ACM/IEEE international conference on human-robot interaction, pp 248–250
58. Babel F, Kraus J, Hock P, et al (2021) Investigating the validity of online robot evaluations: comparison of findings from an one-sample online and laboratory study. In: Companion of the 2021 ACM/IEEE international conference on human-robot interaction, pp 116–120
59. Gittens CL (2021) Remote HRI: a methodology for maintaining COVID-19 physical distancing and human interaction requirements in HRI studies. Inf Syst Front pp 1–16
60. Yam KC, Bigman YE, Tang PM, et al (2020) Robots at work: people prefer-and forgive-service robots with perceived feelings. J Appl Psychol
61. Leite I, Castellano G, Pereira A et al (2014) Empathic robots for long-term interaction. Int J Soc Robot 6(3):329–341
62. Kim SY, Schmitt BH, Thalmann NM (2019) Eliza in the uncanny valley: anthropomorphizing consumer robots increases their perceived warmth but decreases liking. Mark Lett 30(1):1–12

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