Continuous Hospitality with Social Robots at a hotel

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Abstract

Social robots are being increasingly employed in service encounters at hotels. This study explored the possibility that social robots can engage in heartwarming interactions with hotel customers. A collaboration design known as ‘Continuous Hospitality with Social Robots’, in which social robots compensate for gaps in hospitality through heartwarming interaction, was evaluated. A field test was conducted in which social robots engaged in heartwarming interaction with customers in a public area of a hotel and then collected customers’ impressions of the social robots and overall service via a questionnaire and an interview. The results demonstrate social robots’ potential for engaging in heartwarming interactions that enhance overall customer satisfaction through the use of the ‘Continuous Hospitality with Social Robots’ collaboration design. An exploratory analysis suggests that the perceived impressions of the interaction with social robots are influenced by customer gender and the duration of interactions. Furthermore, the results suggest that social robots could be utilized in other roles at hotels, namely effective advertisement through heartwarming interaction and mental support for employees who do not interact with customers.

Keywords Social robots · Heartwarming interaction · Hotels · Hospitality · Collaboration with robots

1 Introduction

1.1 Background and issue

Social robots are being increasingly employed in service encounters at hotels [15, 38]. For example, Henn-na Hotel is said to be the first robot-staffed hotel, where social robots engage with customers at the front desk and act as in-room assistants. Aloft Hotels employ robotic butlers which navigate the hotel and deliver requested items to customer rooms. Moreover, many studies have tested the performance of various social robots in service encounters (e.g. at information desks [24, 32, 40], information broadcasting [26, 27], bellboy tasks [28], and customer feedback gathering [7]).

In service encounters, heartwarming interaction is required for hospitality. Heartwarming interaction occurs when an employee’s behaviour and attitude create

feelings of interpersonal warmth between the employee and their customers. For instance, an employee welcomes a customer with a smile and a sincere greeting, always pays careful attention to a customer, and properly asks if there is anything else an employee could help him/her with. Such interaction is categorized as hospitality or ‘omotenashi’ (Japanese-style hospitality) [23, 31]. This heartwarming interaction—specifically, hospitality—is important in hotel service because such interactions enhance customer satisfaction in the whole hotel service [16], consequently increasing the number of repeat customers and leading to positive word-of-mouth [22].

Here, a question arises: can a social robot engage in heartwarming interaction at a hotel? Some studies mention the effects of heartwarming interaction with robots (e.g. smiling [8], greeting [36, 37]). Although these studies show the possibility that social robots can engage in heartwarming interactions, they did not analyse customer

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reactions in practical hotel situations. It is thus unclear whether heartwarming interaction with robots will contribute to hospitality in hotels because interactions are affected by the surrounding environment and the situational context [33]. Thus, a field test is required in order to establish a connection between robot technology and the service industry. Moreover, the manner in which humans and robots collaborate in hotel service should be considered [25] because the contribution of tools depends on how they are used. Therefore, designing methods for collaboration with robots and subsequently testing them in practical situations is important.

This paper proposes the collaboration design ‘Continuous Hospitality with Social Robots’ and reports on a field study conducted at a hotel to evaluate the design. The design aims to offer interpersonal warmth to customers as often as possible in order to enhance hospitality. For this purpose, social robots compensate for gaps in hospitality; that is, robots are assigned to serve in situations in which a human employee typically does not serve a customer. In this field study, a trial was conducted in which social robots engaged in heartwarming interactions with customers in public areas of a hotel (i.e. a corridor and an elevator hall) throughout the day. To investigate the impact of this heartwarming interaction with social robots, customer impressions of these interactions were collected via a questionnaire and an interview. In addition, differences stemming from personal and situational factors were also highlighted in the analysis. Moreover, other applications of the proposed system were explored, namely effective advertising through heartwarming interaction.

1.2 Research questions addressed by this study

A field study was conducted to evaluate the collaboration design ‘Continuous Hospitality with Social Robots’. During the evaluation, the following questions were addressed:

- Q1 Can interaction with social robots create interpersonal warmth in customers in a hotel environment?
- Q2 Can robots compensating for gaps in hospitality contribute to customer satisfaction in the whole hotel service?

Previous studies have shown that impressions about interactions with social robots are affected by various factors (e.g. the number of robots [26, 27], gender differences [8]). Similarly, in practical situations various factors may affect the impression of the interaction. Understanding these factors is essential for determining the optimal form of heartwarming interaction with social robots. Thus, an exploratory investigation was conducted with focus on the following questions:

- Q3 Does the number of robots (i.e. one vs. two robots), the gender of the customer, or the fact that the customer is alone or in a group affect impressions of heartwarming interactions?
- Q4 Is an impression of heartwarming interaction affected by the number of nights stayed, frequency of use of a hotel, or the amount of time spent interacting with a social robot or a voice-controlled speaker?

In addition, heartwarming interaction may offer a good opportunity to advertise. Thus, customer reactions to a social robot’s recommendations during a heartwarming interaction were investigated by posing the following question:

- Q5 Does a customer follow recommendations from a social robot engaging in a heartwarming interaction?

To answer the above questions, a prototype of a heartwarming interaction system employing social robots was developed and introduced it into a hotel.

2 Literature review

2.1 Social robots in a hotel

Various robots have already been employed in service encounters in hotels [15, 38], and researchers have investigated using social robots for more complex tasks involving human–robot interactions in hotel environments. For instance, a long-term assessment with a humanoid robot was conducted to test and improve robots’ ability to perform bellboy tasks [28]. In the experiment, bellboy tasks involved guiding customers, providing useful information, and providing other hotel-related services. Using robots to gather customer feedback about hotel service was tested with an autonomous mobile robot [7]. Other studies tested humanoid or animal-like robots engaging in information desk tasks in lobbies or customer rooms [24, 32, 40]. In the latter study, Rodriguez-Lizundia et al. focused on the robots’ appearance and behaviour (i.e. with/without robotic body, awake/asleep, and robot/user starts communication) and assessed their effect on the distance, duration, and frequency of communication between robots and customers. In particular, Pan et al. assessed how the number of robots affected the attraction of attention in information broadcasting tasks [26, 27]. While the above studies revealed some technical aspects of robotic design and examined the performance of those designs in service encounter tasks, several researchers suggest that the customer’s interactive experience (e.g. perception and mind)

with a robot should receive greater focus in future research as well [29, 39]. It is believed that heartwarming interaction is one of the most important aspects in human–robot interaction research related to hotel service.

2.2 Heartwarming interaction and social robots

In this analysis, heartwarming interaction is defined as behaviour and attitude which create feelings of interpersonal warmth. Interpersonal warmth is a positive, mild, volatile emotion involving physiological arousal induced by the communication partner's behaviour and attitude [1, 4], and relates to perceived intent, including friendliness, helpfulness, sincerity, trustworthiness, and morality [11]. Management research on hospitality in the service industry has focused on heartwarming interaction [19, 20, 35] because it enhances customer satisfaction with hotel service [16] and consequently increases the number of frequent customers and leads to positive word-of-mouth [22]. In service encounters, heartwarming interaction includes a smile, a greeting, and eye contact [2, 4, 34]. Such interaction is categorized as hospitality or 'omotenashi' (Japanese-style hospitality) [23, 31] and is regarded as emotional labour [21] in the service industry.

In recent years, as social robots have been introduced into encounters in the service industry, the effects of robots' heartwarming interactions have begun to receive attention from some researchers. Chung-En assessed how smiles from a humanoid robot and a human affect customer perceptions in service encounters through a vignette experiment, a method to explain a hypothetical situation and draw participants' perceptions or impressions [8]. It was shown that no statistically significant difference exists between a humanoid robot and a human in terms of feelings of interpersonal warmth. This suggests that social robots can create feelings of interpersonal warmth as effectively as a human employee. In contrast, a laboratory experiment showed that a humanoid robot's greeting to a human is ignored more often than a tele-operated greeting [36] or a human greeting [37]. This result implies that the robot's greeting could not have enough opportunities to create feelings of interpersonal warmth as effectively as a human's greeting. However, these studies do not reveal how heartwarming interactions affect customers in practical hotel situations.

2.3 Collaborative service design for social robots in a hotel

The study examined collaboration with robots in a hotel in which various robots are present [25]. The first form of collaboration involves using robots as a replacement for human labour. Actually, most studies have developed

social robots capable of engaging in tasks typically performed by humans [24, 28, 32, 40], implying an intention to replace human labour with social robots. Henna hotel advocates replacement of human labour with robots for ultimate efficiency [15, 25]. The hotel measured efficiency of labour in terms of time and cost and then assigned humans and robots to each service task in order to improve efficiency as much as possible. On the other hand, researchers anticipated that there would be barriers to these collaborations, including resistance from employees and customers [14]. For example, employees may fear hotel staffing reductions resulting from the labour replacement.

The second form of collaboration involves using robots as a tool to extend hotel service, with the aim of increasing the appeal of a hotel through robotic support [14]. In general, robots are free from the limitations of human labour and human nature. For instance, robots can work without breaks and perform very tedious tasks many times without complaints or forgetting to do them. Thus, robots can be assigned to tasks which are usually not performed by human employees. By doing this, a hotel can offer continuous service to customers during their entire hotel stay. This form of collaboration could allow a hotel to increase service quality because gaps in service are reduced. Moreover, the form does not take the jobs of human employees. Therefore, this form of collaboration would be acceptable in most hotels as the first step in introducing robotic labour. This field study evaluated this collaboration form.

3 Method

3.1 Heartwarming interaction system employing social robots in hotels

This heartwarming interaction system focuses on warm words and informing actions as the basis for heartwarming interactions. The warm words action involves greeting, welcoming, and saying thoughtful words such as 'Good morning', 'We welcome you', and 'Good job today'. The informing action involves providing helpful information such as weather forecasts, the temperature, and accommodation details. Although these actions are very short and can be finished within a single round-trip interaction (e.g. a customer responds with only a 'Good morning' or 'Thank you', and the interaction finishes), they are enough to enhance customer satisfaction with the overall level of service [12, 16, 34].

Starting a conversation ahead of a customer is important in increasing the number of interactions between a social robot and a customer [27, 32]; hence, the actions were implemented as active behaviours instead of passive

Fig. 1 Overview of the interaction system employing social robots **Table 1** State of human position ([x,y]: x-m for corridor, y-m for elevator)

State of human position	Distance (d) and direction to the robot
NON-EXISTENT	$d = \text{null}$
APPROACHING	$d > [7.0, 6.0]$ with approaching
NEAR	$d \leq [3.0, 1.0]$
LEAVING	$d > [7.0, 6.0]$ with leaving

ones. Active behaviour requires detecting a customer's position; thus, a system was developed consisting mainly of two devices (other than a computer): a social robot and a three-dimensional (3D) image sensor capable of recognizing the position of a human. The developed system used desktop-sized (approximately 0.3 m tall) Sota and CommU (Vstone Co., Ltd.) social robots capable of interacting with humans by voice and through arm, face, and head motions. As the 3D image sensor, the system used a Realsense D435/D415 depth camera (Intel Corp.), which is capable of providing RGB and depth images (maximum range of more than 10 m). Human 2D positions were detected from the captured RGB image using the 'OpenPose' algorithm [6], and human 3D positions were computed using the detected 2D positions and the depth image.

Figure 1 shows an overview of our developed system, comprising three components: a human tracking system, a scenario manager, and a humanoid robot. The human tracking system calculates a human's 3D position and their walking direction in the robot coordinate system, using data from the depth sensor; it then sends them to the scenario manager. Based on this information, the scenario manager determines the state of the human position (i.e. 'NON-EXISTENT', 'APPROACHING', 'NEAR', and 'LEAVING'; Table 1). When state transitions occur, the scenario manager selects the proper scenario from the scenario database by referring to a state transition table (Table 2) and then sends a behaviour command (i.e. physical motion and utterance text) to a humanoid robot in accordance with the scenario (e.g. Table 3). A humanoid robot performs the behaviour command

Table 2 State transition table

State transition	Scenario name
NON-EXISTENT → APPROACHING	Greeting
APPROACHING → NEAR	Informing
NEAR → LEAVING	Farewell
LEAVING → NON-EXISTENT	Waiting

using voice synthesis and a behaviour database. For example, when the robot in the corridor detects a customer approaching it, it would say 'Good morning.' with a bowing behaviour, followed by 'It will be warmer today than yesterday.' when the customer walks past it. Finally, when the customer leaves the robots position, the robot will say 'Have a nice day.'

This study prepared two types of heartwarming interaction systems: one using a single robot and one using two robots. The single-robot type is composed of a robot that interacts with passing customers at an entrance or in a corridor. The duration of the interactions with passing customers is short (approximately less than 10 s); hence, the interaction scenario consists of short utterances. When a customer stops in front of a robot, it uses a conversation-end word to induce a customer to leave, such as 'Goodbye' or 'Have a good day.' The two-robot type is composed of two robots interacting with a waiting customer at a lobby or in front of an elevator. The length of interactions with waiting customers is often relatively long, such that a single round-trip interaction cannot fill the time; thus, the interaction time is exceeded, unlike when interacting with passing customers.

In this implementation, the two robots consume the excess time in their conversation by including helpful information and recommendations (i.e. promoting the use of the hotel's accommodations) for a customer. Such interactions were implemented because recent studies have shown that conversations between robots can help smooth lengthier human-agent interactions [3, 13]. They repeat their conversation until a customer leaves. For each system, scenarios are prepared for each time of day (i.e. morning, afternoon, and evening).

Table 3 Examples of the scenario detail

Scenario name	Robots' behaviour
Greeting	Robot(s): say 'Good morning,' 'Good afternoon,' 'Good evening,' 'We welcome you,' 'Good job today,' and so on with a bow behaviour
Informing (corridor)	Robot: say 'It will be warmer today than yesterday,' 'It is sunny day,' 'Wi-Fi password is written on the card holder of your room key,' 'The reception desk is open all night,' and so on
Informing (elevator hall)	[Example 1] Robot A: say 'I got hungry now.' Robot B: say 'Hotel's restaurant is open until 10 p.m.' while looking at a robot A Robot A: say 'Wow, that's great ...' [Example 2] Robot A: say 'I want to charge my cell phone.' Robot B: say 'A customer room has a USB charging port next to the bed' while looking at a robot A Robot A: say 'Wow, that's convenient ...'
Farewell	Robot(s): say 'It's been nice meeting you,' 'Have a nice day,' and so on

3.2 Field study: social robots engage in heartwarming interaction in a public area of a hotel

In order to test the collaboration design 'Continuous Hospitality with Social Robots,' a field study was conducted in which social robots engaged in heartwarming interactions while servicing customers in a hotel which is mainly for business use. To conduct the evaluation, customer impressions of the interaction were collected through questionnaires and interviews. This study was conducted in Tokyo over a 2-week period in late March.

3.2.1 Experimental environment

This field study was conducted on the first floor of a hotel. The floor included 18 customer rooms, and participants can enter the floor only by elevator. Customers other than the participants could not enter the floor during the 2-week experiment. Figure 2 contains a floor map

indicating where the heartwarming interaction systems were installed. The systems were placed in the middle of a corridor and in an elevator hall. The social robots were placed on a stand (0.3 m × 0.4 m × 1 m) at each location. A Sota robot was placed in the corridor, and a Sota robot and CommU robot were placed in the elevator hall. A 3D image sensor was mounted on a 2-m pole to monitor the system.

3.2.2 Procedure

During the 2-week experiment, customers waiting at a reception desk were randomly selected for the field study. The purpose and content of the field study was explained to customers, and they were asked whether they wanted to participate. After customers gave their informed consent to participate in the experiment, they received a gift certificate equivalent to 5000 JPY. For child participants, informed consent was received from both the children and their parents. All participants were assigned to rooms on the first floor. After informed consent, the participants

Fig. 2 Floor map and the position of humanoid robots and sensors

were instructed to use the hotel as usual and submit a completed questionnaire to us at checkout. The participants would interact with the systems when leaving from and returning to the first floor. In addition, they were asked to participate in an interview at checkout.

3.2.3 Participants

A total of 67 Japanese customers participated in the field study; their ages ranged from teenage to over 60 years. Sixty-four questionnaire sheets were collected, 11 of which did not have answers to several items. Accordingly, 53 sheets were used for the analysis. A single customer is defined herein as a customer who stays alone, while a group customer is defined as a customer who stays with family or friends. Thirteen females and 11 males were single customers, while 16 females and 13 males were group customers. The participants stayed at the hotel from one to six nights.

3.2.4 Measurement and analysis

Using a questionnaire, customer impressions of the heartwarming interaction with social robots were collected (Table 4). Items R1–6 are an evaluation of each robot system (R3 is an evaluation for Q1). Items H1–4 are an evaluation of customer satisfaction with the hotel to answer Q2. The items are important aspects of customer satisfaction [19, 22]. Item R6 is an evaluation for Q5. Only those who listened to the robots' recommendations could answer the item. Items P1–3 are an investigation

into the personal attributes of the participants. A 7-point Likert scale was used to evaluate items R1–6 and H1–4 (R1: 1: strongly disagree, 4: no opinion, 7: strongly agree; R5: 1: became much worse, 4: no change, and 7: became much better; and R2–4, R6, H1–4: 1: completely disagree, 2: mostly disagree, 3: slightly agree, 4: moderately agree, 5: strongly agree, 6: very strongly agree, and 7: completely agree). A multiple choice form was used for items P1–3 (P1: 1: this is the first time, 2: less than once a week, 3: less than once a month, 4: less than once a week, and 5: more than once a week; and P2, P3: 1: this is the first time, 2: occasionally, 3: do so at fixed intervals, and 4: do so every day).

A positive answer rate was calculated for items R1–6 and H1–4. A positive answer is defined as follows: R1, R5: ≥ 5 ; R2: ≤ 2 ; and R3, R4, R6, and H1–4: ≥ 3 . They are answers that indicate at least a moderate positive effect.

For the exploratory investigation, a three-way (single or two robots, male or female, single or group customers) analysis of variance (ANOVA) was used for each item in order to answer Q3. A Spearman's rank correlation coefficient was calculated between the questionnaire items and the personal attributes of the participants (i.e. the number of nights, frequency of staying at the hotel, and degree of interaction with social robots and the voice-controlled speaker). The test for non-correlation was used to answer Q4.

In an interview, the participants were asked about the system's merits and demerits, and their expectations of the system. Employees' impressions and awareness about this field test were also gathered.

Table 4 Items in the questionnaire

Item	Question
<i>Impression of robots</i>	
R1(x)	Should x be placed at a hotel?
R2(x)	Did your interaction with x feel intrusive?
R3(x)	Did you feel warm from interaction with x?
R4(x)	Did you enjoy interaction with x?
R5(x)	How did your mood change by interaction with x?
R6	Did you think of following information recommended from robots at an elevator hall?
x = c: a robot in a corridor, e: robots in an elevator hall	
<i>Evaluation for hospitality</i>	
H1	By social robots' service, did you feel Japanese-style hospitality from the hotel?
H2	By social robots' service, did you feel comfort during your stay?
H3	By social robots' service, are you compelled to recommend others to stay here?
H4	By social robots' service, are you likely to stay here again?
<i>Personal attribution</i>	
P1	How often do you use a business hotel?
P2	How much have you interacted with a social robot?
P3	How much have you verbally interacted with a voice-controlled speaker?

Three coders and an experimenter analysed the video data to identify the number and type of interactions that the participants had with the robots. Two coders were assigned to the robot in the corridor, and the other coder and the experimenter were assigned to the robots in the elevator hall. They counted customers who passed near the robots in the video data, and judged whether or not customers ignored the robots. An analysis of the overlapped data (ten percent of the all video data in each case) were well matched (counting passing customers: a corridor Cohen's Kappa $\kappa=0.86$, an elevator hall $\kappa=0.76$; judgement of ignoring: a corridor $\kappa=0.82$, an elevator hall $\kappa=1$).

3.2.5 Results

Figure 3 shows the rates of each answer for each questionnaire item. As for the evaluation of each robot system (i.e. items R1–6), more than 70% of the participants had positive impressions of each system without item R1. In addition, more than approximately 70% of the participants had

positive impressions of their satisfaction with the hotel (i.e. items H1–4). Item R6 was completed by 37 participants.

Several main and interaction effects were identified using the three-way ANOVA of the questionnaire (Fig. 4). A significant main effect, gender, was found in item R1. Compared to males, females more strongly agree that the heart-warming interaction with social robots should be used at a hotel ($F(1, 49) = 4.94, p < .05, ES : r = .30$). Significant interaction effects were found in item R3. Compared to single male customers, single female customers experience more warmth from the interaction with social robots ($F(1, 22) = 5.85, p < .05, ES : r = .46$). With the two robots in the elevator hall, a female also experiences more warmth than a male ($F(1, 49) = 4.32, p < .05, ES : r = .29$). Male customers feel more warmth from the interaction with the single robot in the corridor than with the two robots in the elevator hall ($F(1, 22) = 6.05, p < .05, ES : r = .46$). A significant interaction effect was also found in item R4. Females enjoy interaction with the two robots in the elevator hall more than with the single robot in the corridor ($F(1, 49) = 5.14, p < .05, ES : r = .31$).

Fig. 3 Rates and average of each answer in the questionnaire (the bold portions denote positive answers)

Fig. 4 Average and standard error of questionnaire items for each attribution (analysis of variance, $*p < .05$)

Table 5 shows the correlation coefficients between the questionnaire items and the individual attributes of the participants. Significant weak correlations were found between them. The number of nights was weakly correlated with items R3(c) and R5(e). A longer stay at the

hotel made the customer feel more warmth from interactions with the single robot ($S = 17533, p < .05$) and caused the customer's mood to be enhanced more by two robots ($S = 17379, p < .05$). The degree of interaction with social robots is weakly correlated with item

Table 5 Correlation coefficients between the questionnaire items and the personal attributes of the participants

Item	Number of nights	Frequency of staying at hotel	Experience of interaction with a social robot	Experience of interaction with a voice-controlled speaker
R1(c)	0.239	0.0442	-0.117	-0.0488
R2(c)	0.0212	0.0838	0.198	0.289*
R3(c)	0.293*	-0.0203	-0.297*	-0.225
R4(c)	0.204	-0.0347	-0.191	-0.0904
R5(c)	0.124	-0.119	-0.0571	-0.207
R1(e)	0.158	0.116	-0.0612	-0.0647
R2(e)	0.267	0.135	0.189	0.380*
R3(e)	0.267	-0.141	-0.0189	-0.159
R4(e)	0.138	-0.0919	-0.00127	-0.254
R5(e)	0.299*	-0.101	-0.205	-0.146
H1	0.211	-0.0947	-0.0254	-0.147
H2	0.267	-0.0771	-0.0480	-0.133
H3	0.146	-0.0475	0.00596	-0.172
H4	0.177	-0.00739	-0.0540	-0.183

Spearman's rank correlation coefficient; test for non-correlation, $*p < .05$

R3(c). Those engaging in more interaction with social robots felt less warmth from interaction with the single robot ($S = 32175, p < .05$). The degree of interaction with a voice-controlled speaker was weakly correlated with items R2(c) and R2(e). Those who interacted with a voice-controlled speaker felt more intrusion from interactions with the single robot and the two robots ($S = 17624, p < .05; S = 15381, p < .01$).

Table 6 shows a list of interview answers (23 females and 12 males), through which many comments about merits and expectations were obtained. Some participants left several comments over the categories, and others left comments about only one category. It is noted that the male interviewees provided less comments overall than the female did. As for the merits, many females mentioned positive emotional effects of interactions with social robots (e.g. felt interesting, enjoyable, relieved, non-lonely, brighter, and warm). As for the expectations, participants hoped to talk more with the robots about various things. In addition, we interviewed two members of the hotel's concierge staff that helped us manage the experiment. They provided us with insight into the effects of the robots from the perspective of the hotel staff. Their comments are largely similar to those reported by the customer participants. In particular, the employees reported that they also felt the benefits of the heartwarming interactions with the social robots. Only unique one of them is

that the housekeeping employees were pleased with the heartwarming interaction with robots, which they strongly argued with surprise.

The total number of interaction opportunities (i.e. when a customer passed near the robot) between a customer and a robot was 439 in the corridor, and 946 in the elevator hall. Since some customers were assigned to a room where they would not need to pass by the corridor robot, there were less interaction opportunities in the corridor than in the elevator hall. Participants were found to ignore the robot in 12.5% of the interaction opportunities in the corridor and 26.0% in the elevator hall.

4 Discussion

4.1 Impact of heartwarming interaction with social robots at a hotel

Most participants admitted experiencing at least a slight warmth from the interaction with robots (i.e. items R3). Thus, as an answer for Q1, it was shown that interactions with social robots can provide a heartwarming experience for hotel customers. The results of interviews also support this, because many participants mentioned feeling relieved, less lonely, brighter, and warm from the interactions with social robots. Most participants also admitted

Table 6 List of comments in the interview with customer participants

Category	Comment	Number (females, males)
Merits	Feel cute, interesting, or enjoyable particularly for conversation of two robots at an elevator hall	13 (11, 2)
	Feel relieved, non-lonely, brighter, or warm for robots	8 (7, 1)
	Greeting is nice	4 (3, 1)
	Provided information is useful for me	3 (3, 0)
	It is nice that robots' talk is different in hours and stops at midnight	2 (1, 1)
	Robots trigger a conversation with others	2 (2, 0)
	Small robots are not more intrusive than a human	2 (1, 1)
	Robots may be used for crime prevention	2 (1, 1)
Demerits	Robots seem to be noisy for a room near them	2 (1, 1)
Expectation	More robot responses when talking to them	21 (15, 6)
	More various useful information (guide to a room and around a hotel and current time)	9 (8, 1)
	More various conversations of two robots at an elevator hall	6 (3, 3)
	Smoother conversation (e.g. listenability, responsiveness, and adaptability to a situation)	6 (4, 2)
	Better arrangement (difficult to find, far from my room) & 1 (1, 0)	1 (1, 0)
	Want robots also in a room	1 (0, 1)
	English communication	1 (1, 0)
	Individual recognition	1 (1, 0)
	Better cloth design	1 (1, 0)
	Replace CommU with Sota (CommU is scary)	1 (1, 0)

experiencing at least a slightly positive effect from the interaction with robots on items R2, 4, and 5 (i.e. non-intrusive, enjoyable, and mood). Thus, the system is a beneficial service for many customers from various aspects. On the other hand, the result of item R1 indicated that half of the participants did not need the system at the hotel, although they admitted a positive effect from it. This can be attributed to the service being regarded as a value-added service; that is, it depends on individual demand.

Most participants also admitted experiencing at least a slightly positive effect from the interaction with robots on items H1–4 (i.e. Japanese-style hospitality, comfort, making recommendations, and repeated use). Thus, as an answer for Q2, it was shown that interactions with a social robot can enhance a customer's satisfaction with the overall service at a hotel. The results of the interview, where there were many positive comments, provide further evidence for this finding. However, the current study is limited by the fact that all of our participants were exposed to the social robots, and future work should be conducted to evaluate this question through the use of a controlled experiment.

The findings from the field study indicate that a social robot can engage in a heartwarming interaction that enhances hospitality in a hotel environment, using the 'Continuous Hospitality with Social Robots' collaboration design. This fact could be applied to other fields such as retail, restaurants, and nursing. However, there are several limitations for their implementations. First, cultural and situational factors should be considered. Different situations will require different manners of interaction. Second, the effects of a robot's appearance should also be investigated, by determining whether its traits are humanlike/robot-like/animal-like, and by examining the effects of any physical body parts. If a different robot had been used in this study, the results may have been different. Moreover, the personality of customers is also an important factor which determines their impression of the system. In this field study, participants who were friendly to robots may have been predominant.

The heartwarming interaction system has significant room for improvement as the interview results provide us with clues to improve the system. In fact, some participants could not obtain positive effects from the system. The main comments on expectations indicate that participants hoped the robot would respond to their statements and provide other various useful information and conversations. When employing the designed functions and content, the system could enhance customer satisfaction mostly in terms of hotel service. Moreover, an under-mentioned exploratory investigation suggests several possible impacts resulting from differences in personal and situational attributes; that is, it is important to provide an

interaction that correlates with the individual attributes of customers. Accordingly, individual recognition technology might be an important key to an improved interaction system.

4.2 Effect of personal and situational attributes on impressions of heartwarming interaction with robots

The exploratory investigation suggested possible effect differences resulting from differences in personal and situational attributes. Regarding Q3, the results of the three-way ANOVA suggested differences related to gender. First, males did not value the warmth and enjoyment provided by the two robots in the elevator hall as highly as the females did. In other words, the conversation between the two robots was not an effective interaction for a male. It was inferred that the reason for this was that males generally prefer silence [10], which was also supported by the interview results showing that many female participants found the robots' conversation to be cute, interesting, or enjoyable. It is noted that only a few males felt that way although gender imbalance of interviewees has to be taken into consideration. Thus, it may be preferable to avoid providing excessive interaction with male hotel customers. Second, compared to males, females staying by themselves tended to feel warmth from the interaction with social robots. The warmth felt by single customers seemed to alleviate their sense of loneliness. Considering the interview results showing that some females and only one male participant felt less lonely through the interaction with social robots, it was inferred that the reason for this was that females have greater awareness of their own loneliness. Thus, it is clear that the interaction should be more aggressively provided to single female customers at hotels. It is noted that some studies claim that males simply cannot admit to feeling lonely [5, 9]. Third, females tend to more strongly agree that the heartwarming interaction system should be made available at hotels. It was inferred that females could more readily understand the value of the system because of the tendencies mentioned above.

Regarding Q4, the correlation results suggest an important tendency in long-term interactions with social robots at a hotel. First, significant weak positive correlations were found between the numbers of nights stayed and two items: R3(c) and R5(e). A longer stay allows participants to have more contact with robots; hence, it is inferred that these positive correlations indicate an accumulation of the robots' main contributions. Accordingly, it is concluded that the single robot in the corridor generated additional warmth and that the two robots in the elevator hall contributed to enhancing the

customers' mood. The number of nights stayed was also positively correlated with most of the other items; thus, it is inferred that providing more interaction can generate more positive benefits for a hotel. Second, a significant weak negative correlation was found between the degree of interaction with social robots and item R3(c). Observing the interactions between humans and social robots reveals information about the robots' abilities in terms of recognition, physical movement, and communication skill. A single robot in a corridor only engages in short conversations, unlike two robots in an elevator hall and general social robots; hence, this gap in robotic functionality might cause experienced participants to perceive a lack of warmth. Additionally, significant weak positive correlations were found between the degree of interaction with the voice-controlled speaker and items R2(c) and R2(e). It was inferred that this occurred because interaction with the voice-controlled speaker reduced interest in verbal communication with robots. A similar tendency appears in other studies, in which students tended to gradually lose interest in interaction with social robots during long-term experiments [17, 18]. Thus, when a robot talks to someone uninterested in verbal communication with a robot, the communication would be perceived as intrusive. The same tendency was found in the correlation between the degree of interaction with a social robot and items R2(c) and R2(e), suggesting that greater experience with robots leads to more negative responses by the participant. The present generation will have many verbal interactions with robots or voice-controlled speakers in the near future; thus, attention must be paid to the negative aspects of heartwarming interaction provided by social robots. One possible explanation of this relationship between greater experience with negative responses is that individuals who have used voice assistants and robots in the past perceive them as tools rather than entities that have intention. To achieve the feeling of the heartwarming interactions we focused on in this paper, it is important to imagine the conversation partner's intention. For example, to create interpersonal warmth when being greeted, you must imagine that the partner's intention is to welcome you and to establish a good relationship. However, if the individual regards the robot as a tool, they may not perceive that the robot's intention as described above, and then greeting will become just text information. Since experienced individuals are likely to understand that the robot does not have intention, this can lead to the negative responses and the lack of heartwarming interactions. Finally, note that this repeated testing may cause type I error; hence, reverification is likely required.

4.3 Recommendation in heartwarming interaction

Regarding Q5, interestingly, almost all participants considered following the recommendations from the two robots in the elevator hall. This tendency indicates the potential of using social robots to provide advertising, in addition to providing heartwarming interaction. In advertising research, warmth is an important aspect in improving sales totals through commercials [1]. That is, conveying warmth to a customer induces them to react positively to the provider's advertisement. Hence, our field study shows that heartwarming interaction with a social robot might induce a customer to follow recommendations from the robot. Future research will aim to verify whether human-agent interactions can provide an effective means of advertising.

4.4 Impact of robots' heartwarming interaction with housekeeping employees

Employees' comments revealed an unexpected aspect of the interaction with social robots: housekeeping employees seemed to benefit from heartwarming interaction with robots. These employees clean customer rooms and public areas during the daytime. During that time, they had several opportunities to interact with robots in public areas of the hotel. It is inferred that the housekeeping employees may lack social approval and self-esteem because they engage in behind-the-scenes work, in which they provide service for customers but rarely interact with them face-to-face. In other words, they have little chance to be appreciated by customers, unlike in general service encounter work. In particular, tipping is not customary for hotel cleaning in Japan. Thus, the lack of personal interaction experienced by housecleaning employees might cause them to lack social approval and self-esteem; thus, the robots might benefit these employees through heartwarming interaction.

The above conjecture suggests a novel application of heartwarming interaction; that is, heartwarming interaction supporting the mental well-being of workers engaged in behind-the-scenes work. Because heightened social approval and self-esteem enhance motivation to work [30], heartwarming interaction would be beneficial in terms of employee management. In circumstances in which collaborative work with robots has increased, partnerships between robots and employees should receive greater focus in future research.

5 Conclusion

To explore the possibility that social robots can engage in heartwarming interaction, a prototype employing social robots was developed, and a field study in which

robots provided heartwarming interaction for hotel customers was conducted, using the 'Continuous Hospitality with Social Robots' collaboration design. After collecting and analysing customer impressions of the interaction by questionnaire, it was found that social robots' ability to provide heartwarming interaction enhances customers' overall satisfaction with the hotel services.

This exploratory investigation suggested possible impacts caused by differing personal and situational attributes. First, results show that a heartwarming interaction satisfies females more than it satisfies males. In particular for males, conversations between two robots are relatively ineffective as an interaction service. Second, the contribution of the heartwarming interaction can accumulate day by day and increase customer satisfaction. In more detail, the single robot in the corridor contributed a relatively high degree of warmth, while the two robots in the elevator hall contributed more towards enhancing the customers' mood. Third, the experience of verbal interaction with a robot or a voice-controlled speaker negatively affects the evaluation. People will have many experiences engaging in verbal interaction with technology in the near future; hence, it is important to continually evaluate the negative aspects of heartwarming interaction provided by social robots.

Finally, other applications of the proposed system were examined, namely effective advertising through heartwarming interactions and mental support to behind-the-scenes employees.

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Compliance with ethical standards

Conflict of interest Yuichiro Yoshikawa and Hiroshi Ishiguro consulted for Vstone Co., Ltd., which sells CommU and Sota, and received compensation. Hiroshi Ishiguro also owns stock in the company.

Ethical approval This study involved human participants and was approved by the ethics committee of the Graduate School of Engineering Science at Osaka University (No. 29-14). We obtained informed consent from participants.

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