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Style Matters: Evaluation on Communication Styles of a Restaurant Robot

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Abstract

As more robots appear in society to provide services and assist human activities, there is also a growing need for knowing how to improve social interaction. Communication is a key component for social robots to perform service tasks, and previous studies have shown that communication style plays a role in people's perception of social robots. Since restaurants are public spaces where people expect communications and personal services but few studies have been done in restaurants on communication styles, we conducted three studies to further investigate the effect of communication styles on people's perception of restaurant robots.

Firstly, we interviewed restaurant members ($N = 13$) to investigate the needs in restaurants and the requirements for restaurant service robots. The participants indicated that reception was where they need the most help, and social robots such as the Pepper robot would be able to perform reception tasks. Secondly, based on the interview results, we developed a reception flow for Pepper. We conducted a pilot in a restaurant in Leiden to test Pepper and improved the flow according to the feedback from the pilot. Thirdly, we designed two communication styles for Pepper, namely the task-oriented style and the person-oriented style. We evaluated people's perception of the communication styles using Amazon Mechanical Turk ($N = 343$). The results showed that the communication styles of Pepper had affected people's perception of the communication orientation and the service experience, but not their perception of Pepper's characteristics.

We found that social robots fit reception work best in restaurants, and the task- and person-oriented communication styles affect people's perception of social robots. The effect was specifically on the perception of the communication orientation and the service experience, but not Pepper's characteristics.

Keywords Human-Robot Interaction; Interaction Design; Communication Styles; Social Robot; Reception Robot; Restaurant Robot.

Contents

1 Introduction

Employing robots, artificial intelligence and service automation in industries is a trend that is still accelerating. While robots have been introduced into the manufacturing industry for decades, they are appearing in our lives more frequently in recent years. They provide services in various spaces such as museums, restaurants and hotels (Samejima et al., 2015; Smith, 2015; Eksiri & Kimura, 2015; Zalama et al., 2014; Pinillos, Marcos, Feliz, Zalama, & Gómez-García-Bermejo, 2016). During the outbreak of the COVID-19 epidemic, service robots also helped in hospitals and nursing homes (Ackerman, 2020; UBTECH Robotics, 2020). The International Federation of Robots (IFR) defines a service robot as a robot that helps people or equipment (excluding industrial automation applications) on useful tasks[1]. It ranges from semi-automatic robots, in which human operation is contained, to fully automatic robots which control themselves without operation from humans.

Some of the service robots are socially interactive. They interact with humans and behavior under social norms to assist human activities or provide services to humans in either private or public spaces (Billard & Dautenhahn, 1997; Breazeal, 2002). In the past two decades, the number of studies and applications about social service robots surged. The studies were done in many fields and some of the social robots have already come into use in different environments, such as restaurants, shopping malls and hotels (Kanda, Shiomi, Miyashita, Ishiguro, & Hagita, 2009; Pieskä, Luimula, Jauhiainen, & Spiz, 2012; Pierce, 2015; SoftBank Group, 2020).

As more social service robots are being installed in our society, there is also a growing need for learning how to improve interactions between humans and robots. The communication style of a robot is a factor that influences people's perception of their interactions with robots (Zafari et al., 2019; Saad, Broekens, & Neerincx, 2020, n.d.). Further investigation on the communication styles of robots might help in improving Human-Robot Interaction (HRI) in future.

To study how robots can provide better service the public and how people will perceive the communication styles of robots, restaurants can be ideal places. Restaurants are open to the public and the customers will need personal services, which usually involve communications with staff.

This paper aims to investigate the requirements for use of social service robots in restaurants, design such a robot and evaluate people's perception of the robot's communication styles. The remainder of this paper is structured as follows. In this section, we review some of the relevant works for our project. In Section 2, we introduce our research questions, hypotheses and method. In Section 3 - 5, we present our three studies, namely the restaurant robot requirements, the design of a restaurant robot and the perception evaluation of its communication styles. Finally, we conclude the paper in Section 6.

[1] http://www.ifr.org/service-robots/

1.1 Related Work and Motivation

In the following part of this section, we review the related works from three aspects. Firstly, we review the technology of service robots. Then we reflect on Human-Robot Interaction (HRI) aspect of service robots. Lastly, we introduce the Pepper robot that we used in this project.

1.1.1 Service Robots

The concept of service robots had a history of over one hundred years. The precursors of them were the humanoid robots created for exhibitions and entertainment at the beginning of the last century (Teresa, 2014). With the development of robot technology, a number of studies on service robots in different environment settings have emerged since 2000. Reviewing the previous works would give us an insight into the design and use of service robots.

Robox (Siegwart et al., 2003) was built to guide visitors in the Robotics Pavilion at the Swiss National Exhibition Expo (Fig.1). The robot had a navigation module to automatically guide visitors through several fixed presentation spots; it could track the visitors by the motion detection and face detection; it used the happy, surprised and angry expressions to show the emotion states. A total of 11 Robox robots worked for 159 days in the Robotics exhibition, which had 500 visitors per hour and about 125 on average of these 500 visitors contacted the Robox robots.

A robot was designed to interact with customers in a shopping center (Kanda et al., 2009) (Fig.2). It was tested there for five weeks on three tasks: directing customers, giving advertisements and recognizing regular customers to build relationships with them. The robot equipped a square floor sensor and a gaze system to help the robot detect the customers' locations so it could turn its body towards the customers to interact with them non-verbally. The study found that the robot attracted more visitors for shopping than a traditional information-presenting display, implying that people were interested in service robots in public spaces.

Henn-na Hotel was the first hotel served only by robots (Pierce, 2015). Humanoid robots

Figure 1: Left: the appearance of Robox. Right: Robox is interacting with the visitors at the Swiss National Exhibition Expo (right). From (Siegwart et al., 2003).

Figure 2: The interactive humanoid robot in the shopping mall is interacting with a customer. From (Kanda et al., 2009).

worked at the front desk as receptionists for check-in and information service (Fig.3); an electric arm worked in the cloakroom; and porter robots carried guests' luggage to the rooms, which face identification by camera eyes could unlock. Though the were no evaluation results provided to know how the robots' services were, it was a good case that some robots could help with multiple tasks and serve customers in a hotel.

Care-O-bot (Graf, Reiser, Hägele, Mauz, & Klein, 2009) was able to grab and serve bottle of drinks to visitors and could be used in both private and public environments. It had a sensor to locate and verify the bottle drinks, a gripper to grab the drinks, and a tray with a touch screen to receive users' commands and hold drinks (Fig.6). Though the ability of Care-O-bot was limited with only one function, it successfully served the drinks to the visitors in several events. This suggested that it was important to know the needs in a certain environment then design the functions accordingly.

Sacarino (Pinillos et al., 2016), a bellboy robot who worked in a hotel for 51 days, mostly stood at the lobby to welcome guests and offer information about itself, the hotel, weather, news and upcoming events. The guests could also make options of their breakfasts or call taxi via Sacarino. According to the 53 users' evaluation, Sacarino was useful as a helper and guide in the hotel. This study showed that providing helpful services to users would bring a positive influence on users' perception for a service robot.

A map-indicating humanoid robot named iCub (Holthaus & Wachsmuth, 2014) was tested in Bielefeld University in Germany to give directions on a map of the campus (Fig.5). When it detected someone, it would start to offer help by a dialog and it was also able to point directions with its hands. This study found that social interactions during the service could enhance the user experience.

Besides the service robots we mentioned above, which were designed for events, shopping centers and hotels, there were plenty of service robots designed for restaurants as well. A restaurant humanoid robot, resembling a real female human, was designed and experiments were done in a lab setting (Chen, Gao, Song, Liping, & Wu, 2010). It had a humanoid figure that held a tablet, on which a website was visible for customers to order food. The robot was

Figure 3: Two robot receptionists working at the front desk. From (Pierce, 2015).

Figure 4: The appearance of hotel bellboy robot Sacarino. From (Pinillos et al., 2016).

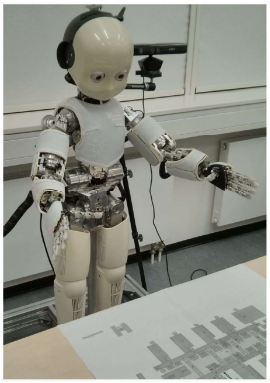


Figure 5: The robot iCub with a testing map in front of it. From (Holthaus & Wachsmuth, 2014).

Figure 6: Left: The appearance of Care-O-bot 3. Right: Care-O-bot 3 is serving bottle drinks to the visitors. From (Graf et al., 2009).

tested in an office, simulating the restaurant environment (Fig.8), not in a real restaurant environment. As such, its actual utility was unclear.

There was a project lasting for four years, from 2009 through 2012, in restaurant branches of MK Company in Bangkok, Thailand (Eksiri & Kimura, 2015). The first two generations of robots, OrderOne and OrderTwo, released in 2009, were designed for order taking. The other three generations, ServeOne, ServeTwo and Slim, released between 2010 and 2012, were designed mainly for food delivery (Fig.9). The robots could greet customers and issue notifications in Thai, English, Chinese and Japanese. They have provided more than 14,000 services during the 30-month experiment period. The study found that though there were problems during the services, most customers and staff responded positively to the robots.

As some robotic restaurants emerged since 2018, robots were reported to work at different positions in restaurants. Haidilao, a popular Chinese hot pot brand, opened a branch on 28th October 2018 in Beijing, China (Edoardo, 2018). The restaurant used robotic arms to prepare dishes (Fig.10), autonomous dining carts to deliver food and specially designed robots to

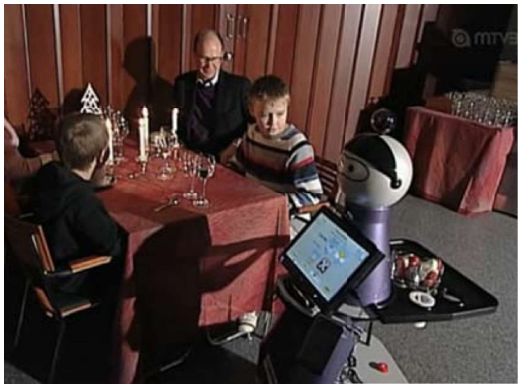


Figure 7: Centria's service robot serving desserts to the customers. From (Pieskä et al., 2012).

Figure 8: The robot in Chen's work being tested in the office. From: (Chen et al., 2010).

(a)

(b)

Figure 9: (a) ServeOne robot moving on the track. (b) the robots from left to right are ServeTwo, OrderOne, Slim, OrderTwo, ServeOne. From (Eksiri & Kimura, 2015).

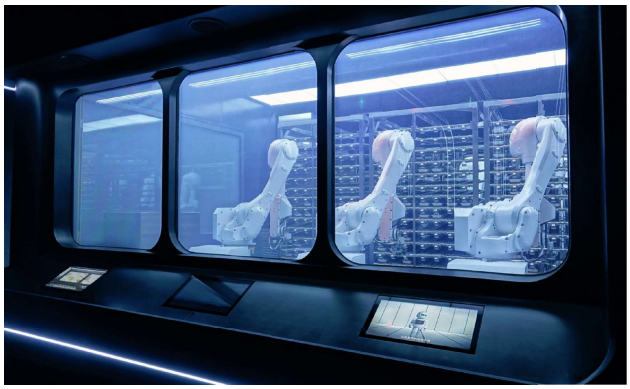


Figure 10: Mechanical robot arms help prepare ordered dishes. From (Edoardo, 2018).

Figure 11: An automatic dining cart serving food to the table. From (Lee, 2018).

help human staff serve food and do the cleaning. Two weeks later, on 10th November 2018, the well-known Chinese retail brand Jingdong, also launched its first unmanned restaurant (Lee, 2018). Customers ordered on phones, the cooking machines and dining carts all worked automatically (Fig.11). Though more novel restaurant robots appeared, they were typically designed to perform service tasks where no social interactions with customers involved.

However, social robots can also help in restaurants. Centria's service robot (Pieskä et al., 2012) was developed based on the robot KOMPAÏ by RoboSoft. It was introduced into two Finnish restaurants. Centria's service robot provided weather information and news to the customers, and it had entertainment functions. Customers could order with its tablet, then food would be delivered on its tray (Fig.7). The study showed that social robots were able to help with various tasks in restaurants. Moreover, the study suggested that social robots had the potential to serve in other public spaces as well.

Recently, social robots like Pepper and NAO were also used in restaurants to serve and interact with customers. Pepper PARLOR (SoftBank Group, 2020) was a cafe in Japan, opened in December 2019 and started using robots such as Pepper to provide services. Pepper was used to orders and interacted with the customers near their seats. It was a step forward that proves the social robots' usefulness of service tasks in practice.

To conclude, by reviewing the previous studies on service robots, we learned two important things. First, a helpful service robot should be designed according to the needs of its serving environment. It would be necessary to investigate the service needs and the special requirements for developing a robot in a particular environment. Second, though the typical restaurant service robots were non-social robots, two works showed that social robots were able to serve in restaurants. Together with the finding that social interactions could enhance the user experience during the service, it would be meaningful to develop a social robot for restaurants and investigate its social interaction in such an environment.

1.1.2 HRI Reflection on Service Robots

The Thai restaurant service robot project showed that most of the staff enjoyed their work with the robots, even though the robot did not function as expected (Eksiri & Kimura, 2015). Having robot colleagues might be a novel experience, as well as being served by robots. There are modalities that a robot can use to perform tasks, such as speech, gestures or facial expressions, while virtual agents like a website or a video-displayed robot cannot. Furthermore, the physical presence of a robot can positively affect people's engagement (Bainbridge, Hart, Kim, & Scassellati, 2011). In the study done by Bainbridge et al. investigated the effect of a robot's presence in interactions, a total of 59 participants interacted with a physically presented robot and also a virtually presented robot. They rated the impression for how natural the interaction was. The results showed that the participants perceived their interactions with the physically presented robot to be more natural. Therefore, we chose to design a physically presented robot to provide better service to customers in restaurants.

For social robots' service in restaurants, communication is a key component. And the communication style plays an important role in people's perception of social robots, which deserves

further study. Interactions among people have been categorized into task and social-emotional (Bales, 1950). A task-focused interaction would aim at completing a task without distractions and a social-emotional-focused interaction involves more emotional communication and reactions. Similarly, another study defined two styles of communication (Miller, 2005). One was task-oriented, in which the conversations would focus more on finishing the task and achieving the goals. Another was person-oriented, in which the conversations would focus more on communicating with the people in conversations.

Derived from humans' communication styles, a study with Pepper indicated that gesture openness, speech acts and chit-chats were the most evident features that distinguish the task- and person-oriented communication styles (Saad et al., 2020). These findings could help future researchers develop robots in task- and person-oriented styles, respectively. And Saad et al. found in their following study that the robot with a person-oriented style was perceived to be more animate and likeable by the users, compared to the robot with a task-oriented style. This finding implied that the communication styles of robots had an effect on people's perception of the robot.

As the communication style is important in social robots' interactions, we can use it as a factor to study the social interaction of a restaurant service robot. The findings can help us explore where the balance is between doing practical tasks (such as food delivery and order taking) and social/entertaining value of a service robot (such as chit-chats between customers and a robot) in restaurants. However, few studies have focused on the communication styles of social robots. Though a study has been done in a hospital setting (Saad et al., 2020), it is still not clear how people will perceive the communication styles of social robots in other different environments, such as restaurants. Therefore, a study on the communication styles of a restaurant service robot is meaningful and will help us understand HRI and design social robots better in future.

1.1.3 Pepper Robot

Humanoid robot Pepper was released in 2014, initially developed by French company Aldebaran (renamed as SoftBank Robotics in 2016) to be a home companion, which can tell jokes and stories, play games with family members, read recipes while they are cooking etc. (Guizzo, 2014). Pepper is 120 cm tall and weighs 28 kg, with a mobile base, a tablet in front of its chest, a touchable head and hands. It has a diverse set of sensors such as infrared sensors, sonars, 2D and 3D cameras.

One year after its release, in 2015, three Pepper robots were tested in French train stations to welcome guests, offer information about train timetable and local tourism (Smith, 2015). In 2018, a Pepper robot was modified by a robotics laboratory to interactively guide tours in the laboratory office space (Suddrey, Jacobson, & Ward, 2018). And Pepper PARLOR cafe, where not only Pepper but also the other two kinds of robots are now working in, was newly opened in late 2019 (SoftBank Group, 2020).

The recent news reported that the production of Pepper was paused (Naik, 2021). However, since Pepper has been tested in multiple environments to interact with people and perform

Figure 12: The appearance of Pepper. From https://www.softbankrobotics.com/emea/en/pepper.

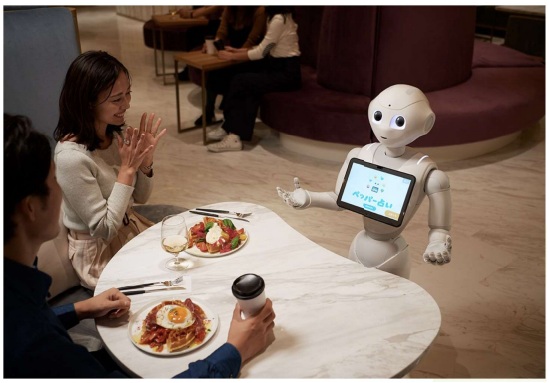


Figure 13: Customers interact with Pepper in the cafe, Pepper PARLOR. From https://pepperparlor.com/en/about/.

service tasks socially, we believe it is qualified to be used in this project to investigate the communication styles of social robots.

2 Research Question

As discussed in the previous section, previous studies have shown that communication styles were influential in interactions between humans and social robots, as well as people's perception of the characteristics of robots (Zafari et al., 2019; Saad et al., 2020, n.d.). These studies offered suggestions on how to develop the task- and person-oriented styles for social robots as well, based on which we could create the two different communication styles of social robots and further investigate people's perception of the robot.

Niemelä et al. have put the Pepper robot in a shopping mall to investigate people's acceptance of social service robots (2017). The results showed that people held a slightly positive attitude towards social service robots when they had no interactions with a robot. After the participants interacted with the Pepper robot, they rated higher perception scores for the social service robots, suggesting that Pepper had positively influenced people's perception of social service robots. This can also be interpreted as a sign that social service robots are generally accepted in human society. We can reset the experiment setting from a shopping mall to another public space to test Pepper's performance and people's perception of it.

Previous studies have shown that social robots were able to help with service tasks in restaurants (Pieskä et al., 2012; SoftBank Group, 2020). Restaurant customers and staff positively responded to the robots (Eksiri & Kimura, 2015). Restaurants are public places where people visit with expectations of communications as well as personal services, which makes restaurants suitable for studies on social service robots. However, as there were few other studies on social robots in restaurant environments, restaurant robots mainly were designed to take orders and deliver food without social interactions. Consequently, we aimed to fill the gap by conducting research in a restaurant environment, expecting to provide useful results to improve future robot designs in restaurants.

Therefore, to investigate the effect of communication styles of a restaurant service robot on people's perception, we proposed the following research questions:
(1) Which service task in a restaurant does a social robot fit best?
(2) What is the effect of task- and person-oriented communication styles on the perception of a restaurant robot?

2.1 Hypotheses

Regarding the second research question, the perception of the restaurant robot would be measured by the perception of the communication orientation, service experience and characteristics of the robot. And we proposed the following hypotheses:
H0 There is no effect of task- and person-oriented communication styles on the perception of a restaurant robot.
H1 There is an effect of task- and person-oriented communication styles on the perception of a restaurant robot.

2.2 Method

We prepared three studies to investigate our research questions.

Firstly, to develop a restaurant robot that performs good services, it is important to know the needs in real work and the requirements for robots in restaurants. We interviewed restaurant members, including waiter/waitresses, owner/managers and a chef, as they had insights into restaurants from their daily work so they knew the needs in restaurants and the requirements for restaurant service robots.

Secondly, according to the interview results, we designed functions and a flow for Pepper to work in restaurants, using the interaction-design tool for multi-modal communication (Saad et al., 2020). We conducted a pilot in a real restaurant in Leiden to test the robot design, during which we collected feedback from the restaurant customers and staff to improve the function designs and the flow.

Thirdly, we designed and filmed the conversations in task- and person-oriented styles with Pepper and created a survey with those videos using Qualtrics[2] to evaluate people's perception of the restaurant robot. We recruited experiment participants on the crowd-sourcing platform Amazon Mechanical Turk[3]. And the result data was analyzed using a professional statistical analysis platform, SPSS[4].

[2]https://www.qualtrics.com/
[3]https://www.mturk.com/
[4]https://www.ibm.com/products/spss-statistics

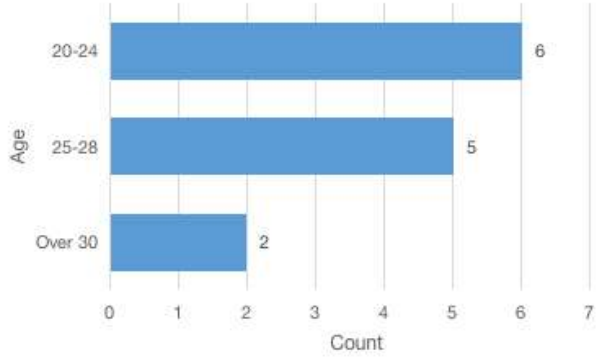
3 Study 1: Interviews for Restaurant Robot Requirements

3.1 Setup

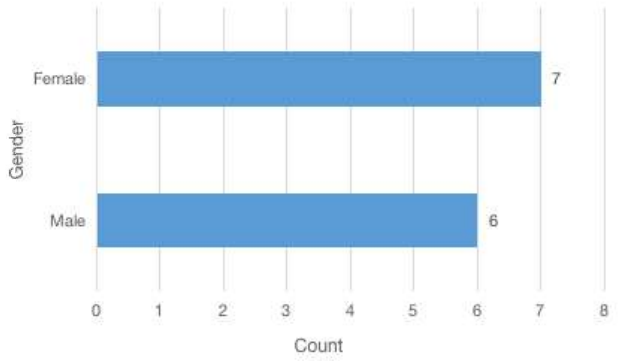
In order to know the service tasks that were in need and could be done by a social service robot in real restaurant environments, we interviewed 13 restaurant employees with 14 interview questions from several restaurants across multiple countries. All the interviews were done online, except for a face-to-face interview with a restaurant owner in Leiden, the Netherlands. The interviewed restaurant employees (N = 13) were in different ages, roles, nationalities, which might help provide comprehensive results from multiple perspectives. And they had never got any hints about Pepper (e.g., a picture of Pepper) before the interviews. The 14 interview questions were from 5 main aspects: (1) the participants' general robot perception; (2) the expected appearance of a restaurant service robot and the functions that would help in their work; (3) how they thought about Pepper's capability; (4) their willingness to work with robots; and (5) their expected reception functions of a social restaurant robot.

The ages, genders and roles of the interviewees were illustrated in Fig.14a-14c. 11 out of 13

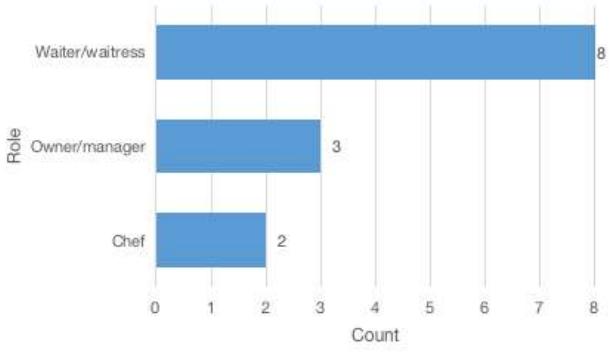
(a) Age of the participants



(b) Gender of the participants



(c) Role of the participants



(d) Capacity of the restaurants

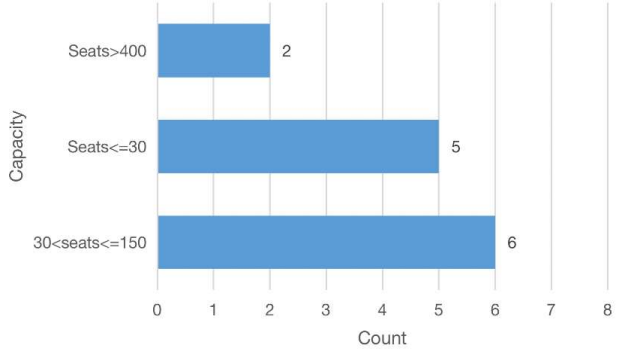


Figure 14: Distribution of the interview participants and the restaurants they worked (N = 13).

participants were between 20 and 28 years old. The genders were also well-balanced with 6 males and 7 females. The roles of the participants were mostly the waiters/waitresses, counting 8 participants. There were 3 restaurant owners/managers, and also 2 worked in kitchens as a chef and a kitchen helper. Tab.1 listed the total 8 nationalities of the participants. 5 participants were from the West and 8 were from the East.

Tab.2 shows the locations of the restaurants where the participants work. 5 restaurants were in the Netherlands (3 in Leiden) and the other 8 restaurants locate in China, Korea, Japan, Italy and Georgia. The capabilities of the restaurants were shown in Tab.14d. Most were less than 120 seats, but there were 2 big restaurants with a capacity of over 400 people.

Tab.3 lists 5 main aspects of the interview questions and the corresponding summaries of participants' answers. To avoid introducing bias by asking questions directly related to reception work, the interview mainly consisted of open questions.

3.2 Results

The interviews started with the questions about the participants' personal experiences and feelings about robots, aiming to investigate their general robot perception. 6 participants had interacted with robots before, 7 had not but they were curious about robots. All of the participants expected the robots to perform useful tasks and show up in public spaces. They also presented their interests in interacting with robots. When asked about service robots specifically, 6 of the participants couldn't give a certain answer because they had no experiences with service robots while 4 participants said that there were still many limitations of service robots. For example, some service robots were inflexible and couldn't understand the customers correctly, and the customers in restaurants might prefer having a human waiter to answer their questions. Though several participants were thinking negatively of the robots, 3 participants

Table 1: Nationalities of the participants.

Nationality	Count
Dutch	2
Italian	1
Georgian	1
Slovakian	1
Chinese (in China)	2
Chinese (in Korea)	2
Japanese	2
Indian	1
Indonesian	1

Table 2: Locations of the restaurants.

Country (city)	Count
The Netherlands (Leiden)	3
The Netherlands (Schipol)	1
The Netherlands(Maastricht)	1
China	2
Korea	2
Japan	2
Italy	1
Georgia	1

Table 3: Summary of the interviews

No.	**Aspect**	**Result**
1	General robot perception	Though the participants had different experiences among robots, all of them were holding optimistic attitudes toward robots in public spaces and were willing to interact with them. The majority did't mind receiving services from robots but the abilities of service robots were considered to be insufficient to offer good services.
2	Expected appearance and functions of a restaurant service robot	The appearance could be a novel look, or a normal humanoid-look. The most expected function categories were the reception and the cleaning, being mentioned 9 times respectively in the interviews.
3	Pepper's capability	After watching a video of Pepper, 9 out of 13 participants proposed that Pepper could do reception work in restaurants, though most of them did't believe(/didn't know if) Pepper had sufficient capability to do it well.
4	Willingness to work with robots	The participants would regard the robots as their colleagues but not helpers. Most of them were willing to co-work with robots in restaurants. They did't think robots could replace humans in a near future due to the limitations of the current technologies.
5	Expected reception functions	Greeting, service enquiry, reservation check, table assignment, route guidance, information offering and entertainment.

proposed some tasks that robots would be good at. For instance, cleaning work done by robots could be more reliable because the robot wouldn't loaf on jobs. They thought having service robots was a cool idea and robots could be actually very useful. 10 out of the 13 participants didn't mind being served by robots, while 3 participants thought it would be troublesome if the robots didn't understand what the customers meant, or the customers just enjoyed the communications with human staff.

The second aspect of the questions was about the expected appearance and functions of a restaurant service robot. The appearance of the restaurant service robot didn't need to be humanoid according to the responses. It could have interesting and attracting non-humanoid appearance, or have a normal humanoid-look. 3 participants even didn't expect service robots to be humanoid at all. The participants mentioned 3 types of functions: reception (organizing seats, guiding customers, taking orders, answering menu questions etc.), cleaning (washing dishes and cleaning tableware etc.) and serving (delivering food, filling drinks, doing payments etc.) Other functions mentioned were security, entertainment, language translation, cooking etc. The participants considered that robots were not sophisticated enough to work professionally like human staff. It might be especially difficult for robots to handle issues involving emotions (e.g., complaints) and the work pace was expected to be slowed down because of the software errors or hardware failures.

Then a video of Pepper working in a shoe retailing store was shown to the participants and we asked about their perception of Pepper's capability. 9 participants believed Pepper could perform reception-related tasks. Example reception tasks proposed by the participants for Pepper included welcoming customers at the door, sending out the waiting numbers, assigning tables for customers, showing them the seats, ordering food, accepting payments. The participants also mentioned serving food and drinks for 5 times, cleaning-related work for 4 times, security work once, attracting and entertainment once and ingredient preparing in the kitchen once. A participant said that a robot would be effective and productive because there were no emotions and or physical factors involved, such as being busy and tired that could negatively impact doing its work. When talking about the real capability of Pepper to accomplish these tasks, the participants were generally holding neutral to negative attitudes. Several participants considered that humans would do better at taking orders. In the participants' view, current technologies were not enough to support Pepper well to accomplish the expected tasks. Pepper might be more accepted, for example, if it could provide reliable information about the menu and could communicate with customers fluently without misunderstanding.

Questions were asked to investigate the willingness of restaurant staff to work with robots as well. It was shown in interviews that the participants would regard robots as colleagues instead of just their helpers. Most of the participants were willing to work with robots and several of them would be excited and proud of this. They would like to take the responsibility of operating the robots as well. However, there was a participant who didn't mind working with a robot but wouldn't trust its ability. And 2 participants directly refused to co-work with robots. One participant would personally feel uncomfortable working with robots. As an owner of a restaurant, she hoped to keep her restaurant being people-oriented. The other participant didn't want to work with robots because she thought the robots were unable to work well in restaurants. The hardware of robots and the artificial intelligence technology still needed improvements to be more advanced. This was also why the participants generally believed that

if the service robots didn't have professional skills, humans would not be replaced by robots in restaurants.

Then we asked about their expected functions for the reception work specifically. There were 7 main functions proposed by the interviewees: *greeting* including detecting the customers, greet them and initiate the conversation; *service enquiry*, which was to ask the customers what services do they need; *reservation* check, which was to check the reservations for the customers; *table assignment*, which was to assign an available table for the customers; *route guidance*, which was to guide the customers to a designated point, such as their seat or the toilet; *information offering*, which was to provide information about the menu, food options, the city etc; *entertainment*, which was to interact with customers while they were waiting for serving. Though a few interviewees believed robots could be used to take orders, several other participants thought it was better to leave this task to human staff.

Although service robots for restaurants still had a long way to go, this interview proved that from the perspective of restaurant employees that reception work was important in restaurants and they believed Pepper would be suitable as a receptionist.

4 Study 2: Restaurant Robot Module Design & Pilot Testing

4.1 Design

We designed the restaurant robot modules based on the previous interview results, our research questions and the latest COVID-19 measures. As we aimed to investigate the different communication styles of a restaurant robot, we focused on the functions which involved many conversations, such as greeting and table management (reservation check and table assignment). And in consideration of the COVID-19 measure that restaurants could only open the outdoor area for customers, we left out some functions that were hard for Pepper to perform outdoors, such as route guidance. As a result, we designed three main modules for Pepper: *Greeting and table management*, *Restaurant history*, and *Menu*. Pepper would interact with customers mainly by speech, together with some upper-body moves. Pictures and text related to the conversations would be shown on the tablet on Pepper's chest to help understand the information as well.

The flowchart of the reception tasks of Pepper is illustrated in Fig.15. When Pepper detected customers, it would start reception service by the module *Greeting and table management*. Pepper would initiate the conversation by greeting the customers, then ask whether they have symptoms like sneezing, coughing or fever. If the customers were in good health condition, Pepper would remind them about the latest COVID-19 measures, such as keeping a distance of 1.5 meters and disinfecting hands. After the COVID-19 instructions, Pepper would continue the reception by checking their reservation. Then in the module *Restaurant history*, Pepper would introduce the history of the restaurant if the customers were interested. And if the customers would like to see the menu, Pepper would provide information in the module *Menu*. As there was a significant doubt on whether a robot was capable of order-taking, this task

would be left for Pepper's human colleagues.

4.2 Pilot

After we built the prototype of Pepper with the three modules, we conducted a pilot at Lab071, Leiden, to see how Pepper performed in a real restaurant and how the customers and staff

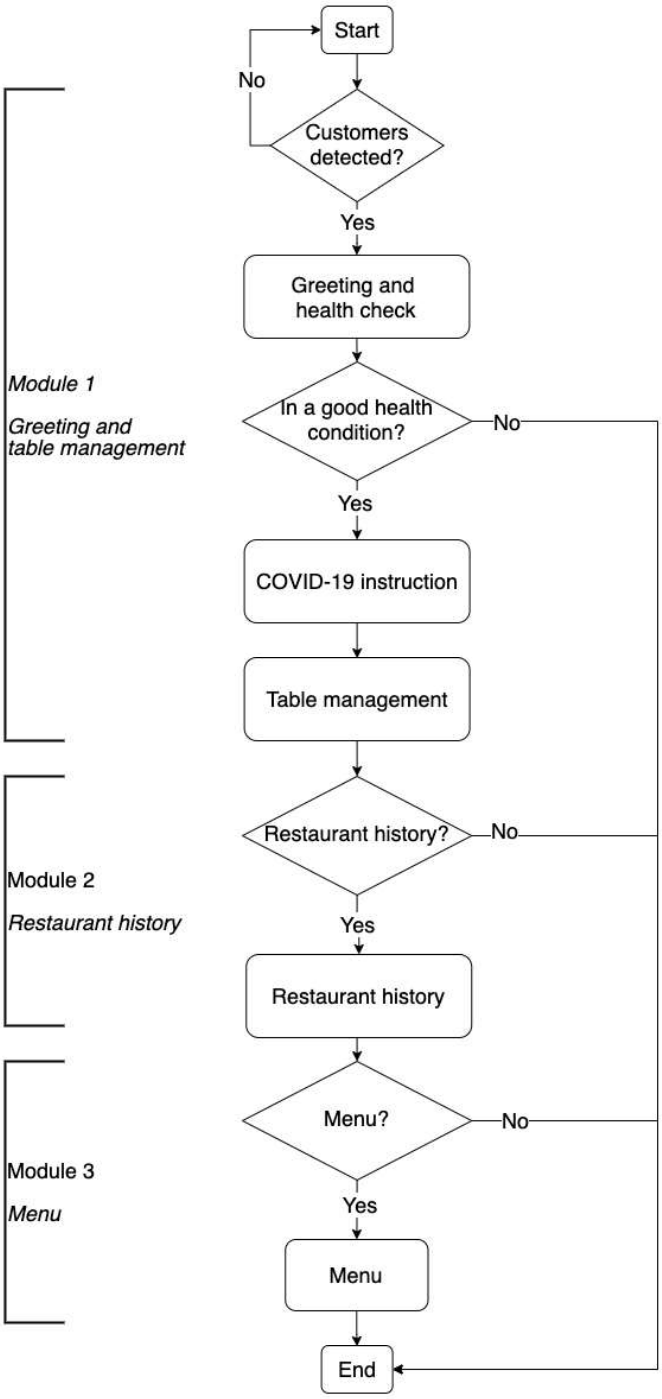


Figure 15: The flow of the reception tasks.

reacted to its presence.

We put Pepper near the restaurant entrance and Pepper drew the attention of almost all the customers. We invited around 10 staff and customers to interact with Pepper. The participants were curious about Pepper and some of them have already seen Pepper on TV. They thought Pepper's moves were gentle and friendly, the interaction flow was smooth in general, and the overall experience was fun and new. Nevertheless, there were some points to improve as well. The speech of Pepper was a bit fast, and sometimes the speech was not clear due to the background noise (the music played by the restaurant and other customers talking). This also had an impact on Pepper, as it might wrongly take the noise as participants' speech input and needed more time to process the input. Furthermore, when Pepper asked questions to the customers, some questions were too long or the words used were unclear, so the participants did not know how to respond, even the robot repeated the questions. The restaurant staff suggested that we should leave out the table assignment function because there were no numbers on their tables, customers might change their table or the staff might take customers to a different table during the seating process. The table assignment would not be beneficial to their work.

Then we improved the prototype based on the feedback we collected from the pilot. At the beginning of the interaction, Pepper would instruct users to speak louder for more precise input. We refined Pepper's speech to make it right to the point. Pepper would always guide users with closed questions, as predictable and concise answers would help in Pepper's speech recognition during conversations. And to make room for the interactions with users, we adopted shorter questions in Pepper's speech and also shorter text to show on its tablet. We turned up the volume of Pepper's speech output so that users could hear it clearly in a restaurant with some background noise. We took the restaurant staff's suggestion about the table assignment that we skipped this function since it would not help much with their work. We kept the reservation check as it was required as a COVID measure.

To conclude, the restaurant customers and staff were curious about Pepper and their interaction experiences were nice overall. With the feedback and suggestions from the pilot, we fixed some problems of Pepper's functions and refined the flow to make it fit the restaurant reception work better.

5 Study 3: Communication Style Design & Perception Evaluation

5.1 Design

To investigate the effect of task- and person-oriented communication styles on the perception of a restaurant robot, we first designed two different styles of Pepper, in accordance to the method suggested in (Saad et al., 2020).

In the task-oriented style, Pepper's speech acts were more formal and shorter with no chit-chats nor personalized comments, heading to accomplish the task fast. Pepper would focus

Figure 16: Part of the interactions of the module *Greeting and table management* in the design panel.

Table 4: Comparison of part of the dialogues in the module *Greeting and table management*.

Task-oriented style	
**P = Pepper; C = Customer.*	
P:	Hi! I'm Pepper. I may not hear you well, so please speak loud and clear. And I will collect the required COVID-19 information from you. Do you have symptoms like sniffing, coughing or fever?
C:	No.
P:	Don't forget to keep a 1.5-meter distance from others. And remember to disinfect your hands regularly as well.

Person-oriented style	
P:	Hi! I'm Pepper. How are you?
C:	I'm good.
P:	Great to hear. I'm happy to see you. I may not hear you well, so please speak loud and clear. And I will collect the required COVID-19 information from you. Do you have symptoms like sniffing, coughing or fever?
C:	No.
P:	I have never gotten a cold. But I often have... Electrical problems. And do you disinfect your hands regularly?
C:	Yeah, I do.
P:	You did well, we have to take it seriously. Keeping distance is also an effective way to control the pandemic. Do you always keep a distance of 1.5 meters from others?
C:	Sure.
P:	Great! It is important to follow the measures, for your safety and also the safety of others.

on the reception tasks only and skip all the chit-chats to keep the conversation concise and efficient.

In the person-oriented style, conversations were more informal and longer with chit-chats. Pepper would make comments, ask questions, tell jokes, etc., to interact more with customers. For instance, Pepper would start a chi-chat commenting on the weather when it greets a customer. After checking the customer's health condition as required by COVID-19 measures, Pepper would tell a joke:"I've never gotten a cold. But I often have electrical problems." And when the customer finished reading the menu, Pepper would try to interact with the customer, saying "I have a personal question out of curiosity. Do you like desserts?"

Tab.4 showed examples of Pepper collecting required COVID-19 information from customers in each style. In the task-oriented style, the conversation was straightforward with a quick greeting, a required question about the customer's health condition and a brief reminder of the COVID-19 measures. And in the person-oriented style, Pepper would greet the customer, tell a joke and give instructions of COVID-19 measures using a more informal tone and in an interactive way.

5.2 Experiment Setup

Because of the COVID-19, we arranged the experiments online. Therefore, we created a survey using Qualtrics and recruited the participants on Amazon Mechanical Turk. First, we filmed 2 videos of Pepper doing reception work in a restaurant setting as shown in Fig.17. One video was in the task-oriented communication style and the other was in the person-oriented communication style. Each survey participant would be assigned to watch one random video without knowing the communication style in the video. After watching the full video, the participant would fill out a survey on a 5-point Likert scale (a higher score means a better result).

5.2.1 Measures

The initial 2 questions of the survey were about the perception of the communication style ("To what extent was the communication style of the robot task-oriented?" and "To what extent was the communication style of the robot person-oriented?"). Then the participants would rate 7 statements (e.g., "I would be willing to follow the COVID-19 measurements suggested by this robot") for the perception of the service experience. The next was the perception of the robot, measured by 4 groups of questions from the GodSpeed questionnaire (Bartneck, Kulić, Croft, & Zoghbi, 2009), namely questions of anthropomorphism, animacy, likeability and perceived intelligence of the robot. Besides the perception questions, the survey also collected demographic information from the participant, including the gender, age, education level, employment and previous interaction experience with humanoid robots.

5.3 Results

To verify the hypotheses, we used 3 measures to evaluate people's perception of Pepper in the different communication styles. The measures were described in Section 5.2, which were

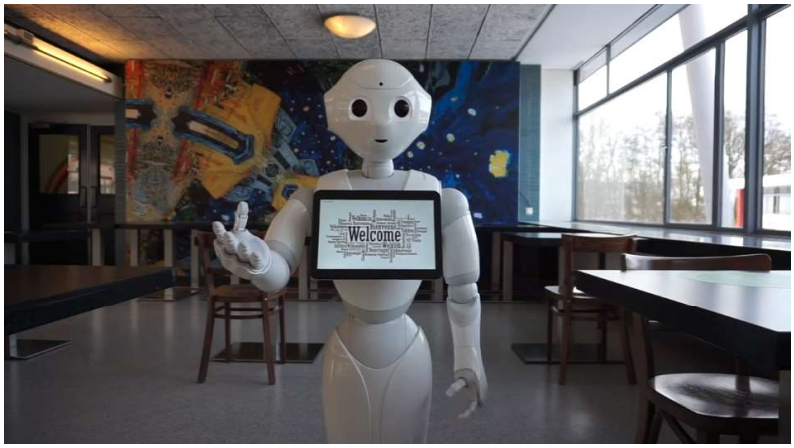


Figure 17: Pepper filmed in a restaurant setting.

the perception of the communication orientation, the perception of the service experience and the perception of the robot. We conducted Multivariate ANOVA to analyze the data (the independent variable was the communication style of the videos, namely the task-oriented video and the person-oriented video).

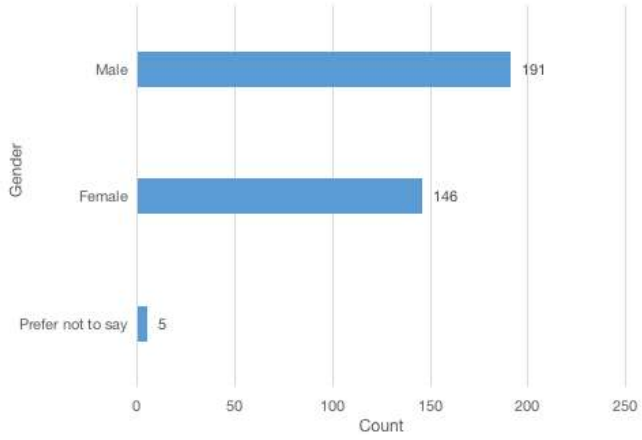
Fig.18 illustrates the demographic information of the participants(N = 343). In the participants, 191 (55.7%) were male and 146 (42.6%) were female, with 5 preferring not to say. Most of the participants were 25-34 years old (34.4%, N = 118), followed by 35-44 (24.8%, N = 85) and 45-54 (21.6%, N = 74). Moreover, 278 (81.0%) had an education level higher or equal to the college degree. Most of them were full-time employee (73.8%, N = 253) and 186 (54.2%) had no experience interacting with humanoid robots.

5.3.1 Perception of the Communication Orientation

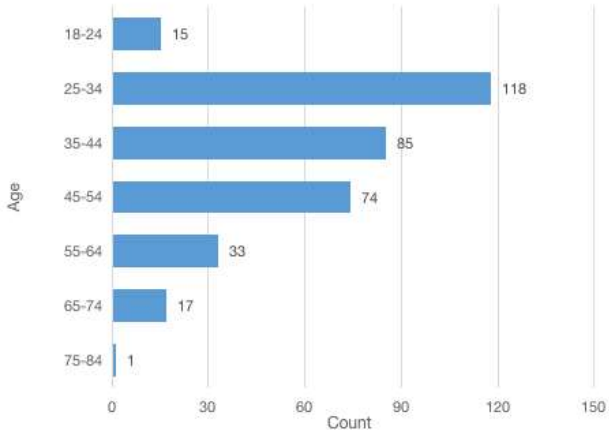
After watching a video of Pepper interacting with a customer, the participants rated how much they perceived this conversation as task-oriented and person-oriented. As shown in Tab.5, the perception of the communication orientation was significantly different (Multivariate ANOVA, $F(1,341) = 38.74$, $p = .000$ for the perceived task orientation; and $F(1,341) = 29.88$, $p = .000$ for the perceived person orientation). Fig.19 illustrates that the task-oriented video was perceived to be more task-oriented ($Mean = 3.61$, $SD = .95$) than the person-oriented video ($Mean = 2.96$, $SD = .97$). And the person-oriented video was perceived to be more person-oriented ($Mean = 3.99$, $SD = .77$) than the task-oriented video ($Mean = 3.40$, $SD = 1.18$).

The results indicated that the participants had a strong sense of the communication orientation of the videos, which meant that the participants' perception to the communication orientations was significantly affected by the communication styles of Pepper.

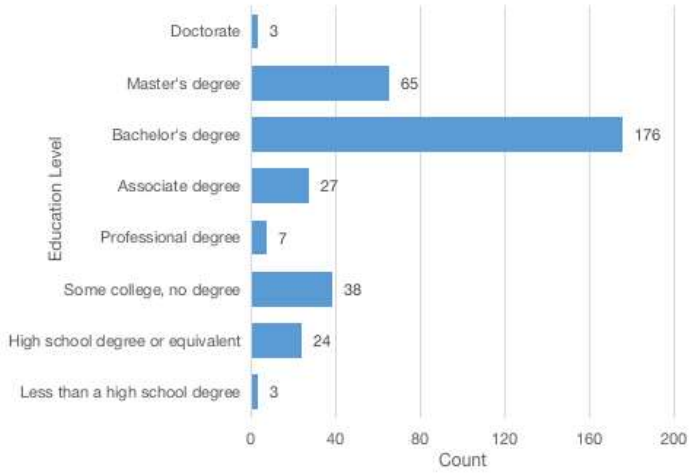
(a) Gender



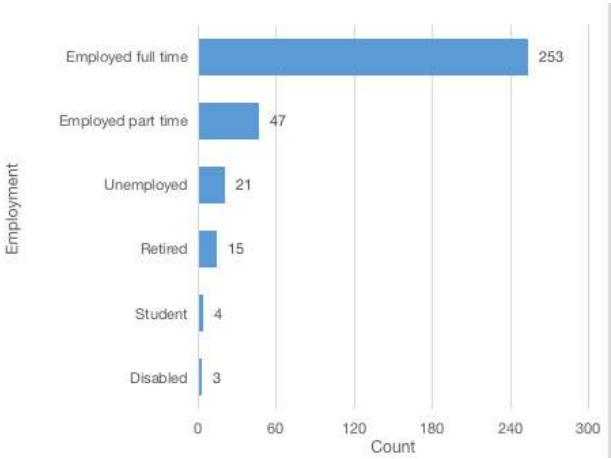
(b) Age



(c) Education level



(d) Employment



(e) HRI experience

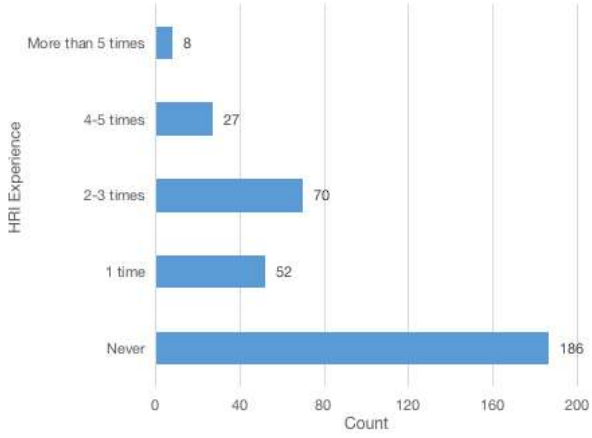
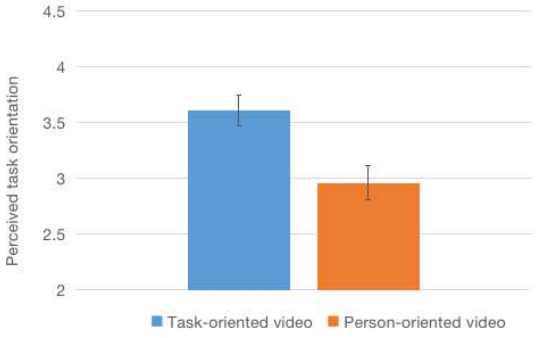


Figure 18: Distribution of the demographic information of the participants ($N = 343$).

(a) Perceived task orientation



(b) Perceived person orientation

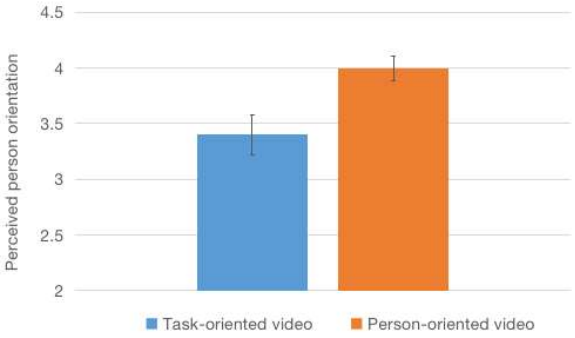


Figure 19: Perceived task and person orientations of the videos by means with error bars showing 95% CI.

Table 5: Perceived communication orientations of the videos.

	Task-oriented video		**Person-oriented video**			
Measure	**Mean**	**SD**	**Mean**	**SD**	**F(1,341)**	**p**
Perceived task orientation	3.61	.95	2.96	.97	38.74	.000
Perceived person orientation	3.4	1.18	3.99	.77	29.88	.000

Table 6: Perceived service experience of the videos.

		Task-oriented video		**Person-oriented video**			
No.	**Measure**	**Mean**	**SD**	**Mean**	**SD**	**F(1,341)**	**p**
1	COVID adherence	4.39	.80	4.10	1.05	8.59	.004
2	More restaurant history	3.15	1.27	2.98	1.34	1.46	.227
3	More menu info	3.81	1.06	3.72	1.17	.545	.461
4	More chit-chat	3.27	1.31	2.91	1.37	6.28	.013
5	See the robot for real	3.42	1.40	3.05	1.36	6.45	.012
6	Be greeted for real	3.32	1.39	3.09	1.32	2.37	.125
7	Conversation too long	3.51	1.19	4.16	1.08	27.63	.000

*A higher score represented more agreement toward the statement of the measure (listed below).
No.1 = *I would be willing to follow the COVID-19 measurements suggested by this robot (e.g., disinfect my hands and the robot's tablet).*
No.2 = *I would like to know more about the history of this restaurant with the help of this robot.*
No.3 = *I would like to know more about the menu with the help of this robot.*
No.4 = *I would be willing to continue talking or chit-chatting with this robot.*
No.5 = *I would like to see a robot like this present in a real restaurant.*
No.6 = *I would like to be greeted by a robot like this in a real restaurant.*
No.7 = *For a real restaurant robot, the conversation in the video is long and tedious.*

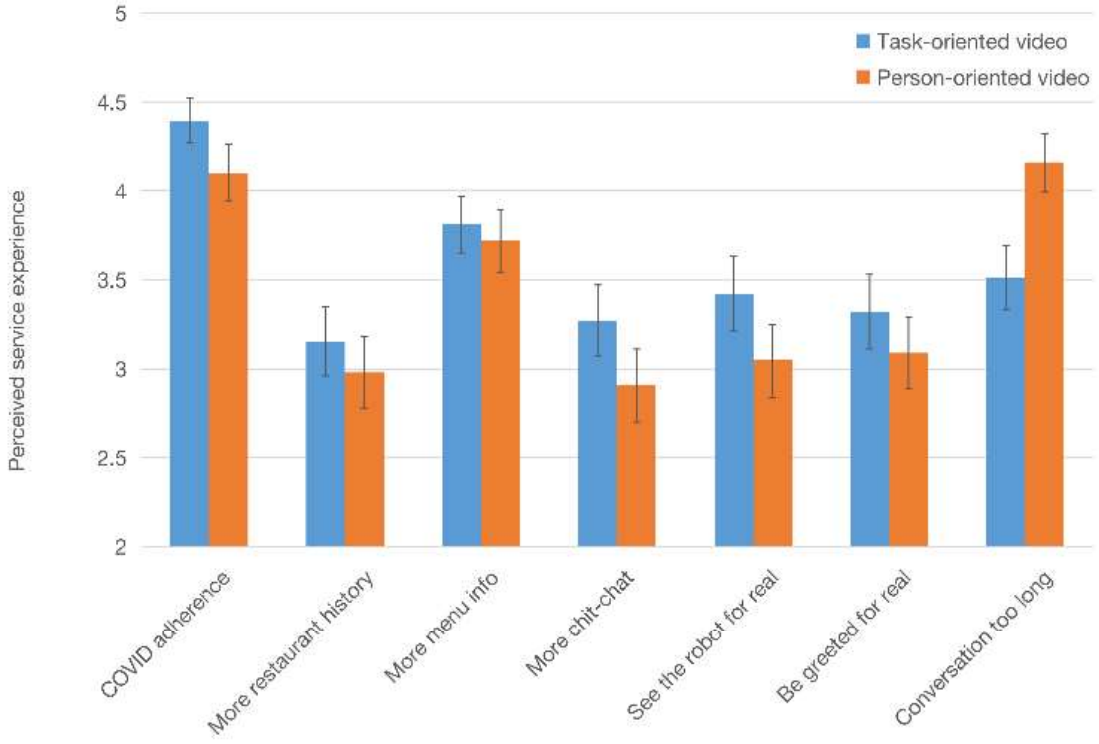


Figure 20: Perceived service experience of the videos by means of each measure with error bars showing 95% CI.

5.3.2 Perception of the Service Experience

In the next section of the survey, the participants rated their impression of the service experience in the videos on 7 measures respectively (Tab.6). The measures No.1, 4, 5 and 7 were significantly different (Multivariate ANOVA, $p < .05$, and $F(1,341) = 8.59$, 6.28, 6.45 and 27.63, respectively) and with the overall perception of the service experience was significantly different on the communication styles of Pepper (Multivariate ANOVA, $F(7,335) = 5.99$, $p = .000$).

Focusing on the 4 significant measures, we found that the the participants who watched the task-oriented video would be more willing to follow the COVID-19 measures suggested by Pepper, would more like to chit-chat with Pepper, and more expected to see and be greeted by Pepper in a real restaurant. And the participants agreed that the conversation in the person-oriented video was too long, compared to the conversation in the task-oriented video (*Mean* = 4.16, *SD* = 1.08; and *Mean* = 3.51, *SD* = 1.19, respectively).

The results showed that the communication styles of Pepper had affected the overall perception of the service experience. The participants were more interested to continue interactions with task-oriented Pepper and they would be more willing to see a task-oriented robot in a real restaurant as well.

5.3.3 Perception of the Robot

To know the participants' perception of the robot itself, we used the GodSpeed questionnaire (Bartneck et al., 2009). It evaluated the robot's anthropomorphism, animacy, likeability and perceived intelligence. The participants rated these 4 measures after watching a task-oriented or person-oriented video.

We did Reliability Analysis on the 4 measures (Tab.7), since there were 5 sub-questions included in the anthropomorphism, likeability and perceived intelligence measures, and 6 sub-questions included in the animacy measure. The results showed that all measures had a good internal consistency ($\alpha > .80$).

Tab.8 shows the results that the participants' overall perception of Pepper was NOT significantly different on the communication styles of the Pepper (Multivariate ANOVA, $F(4,338) = 2.11$, $p = .079$). Fig.21 illustrates that the participants' perception of Pepper remained similar, no matter which video they watched.

5.3.4 Discussion

The results indicated that the communication styles of Pepper significantly affected people's perception of the communication orientation and the service experience, but not people's perception of Pepper itself.

(1) Part of our results was consistent with (Saad et al., n.d.), in which study they found that different communication styles had affected people's perception of the communication orientation (e.g., the task-oriented designs were perceived to be more oriented toward the task and less oriented toward the person). Furthermore, we proved that the communication styles would affect people's perception of the service experience as well.

Table 7: Results of the Reliability Analysis of the GodSpeed questionnaire measures.

Measure	α	**N of Items**
Anthropomorphism	.91	5
Animacy	.86	6
Likeability	.89	5
Intelligence	.89	5

Table 8: Perceived robot characteristics in the videos.

	Task-oriented video		**Person-oriented video**			
Measure	**Mean**	**SD**	**Mean**	**SD**	**F(1,341)**	**p**
Anthropomorphism	2.93	1.16	2.98	1.08	.16	.688
Animacy	3.41	.87	3.40	.86	.01	.939
Likeability	3.97	.77	4.00	.84	.11	.736
Intelligence	4.04	.811	3.89	.82	2.76	.098

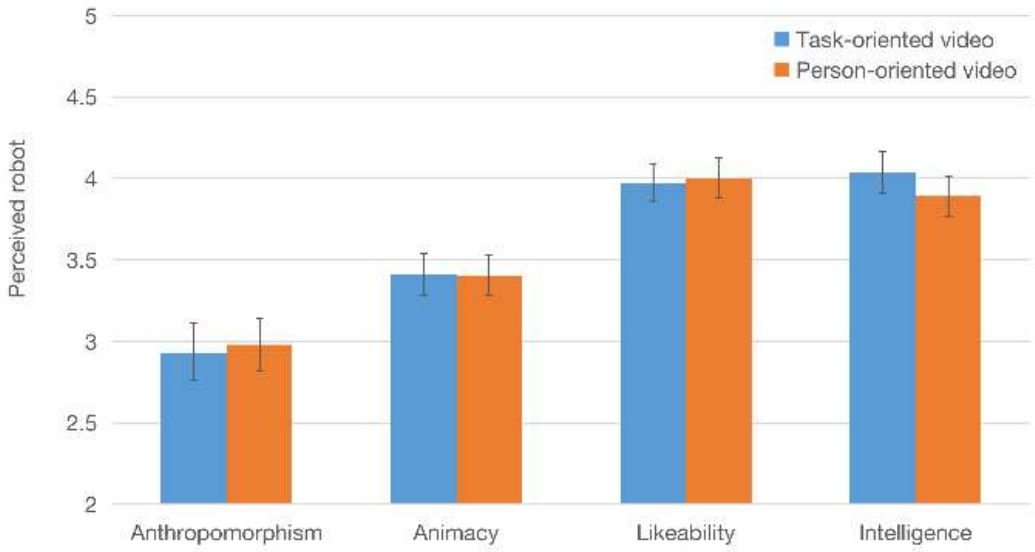


Figure 21: Perceived characteristics of the robot in the videos by means of each measure with error bars showing 95% CI.

However, we had different results on the perception of the robot's characteristics. Saad et al. found that, compared to the task-oriented robot, the person-oriented robot was perceived as more animate and likeable. But our results showed that people's perception of the robot's characteristics was not affected by its communication styles. In our case, we built a general function flow of Pepper first, then we designed the two different communication styles based on the same function flow. No matter which communication style Pepper used to communicate with the customers, it provided the same service to the customers. In other words, even if Pepper communicates with people in different styles, as long as it provides the same service to people, the customers will not feel differences on the characteristics of Pepper itself.

The discussion above suggests that it is possible to manipulate the communication styles without changing people's impression of the robot. Suppose other studies require the participants' perception of the robot's characteristics unchanged but the perception of the communication orientations and the service experience to be different. In that case, a possible way can be keeping the robot's functions the same but only modifying the robot's speech acts and chit-chats in different styles.

(2) The results from (Zafari et al., 2019; Saad et al., 2020) indicated that people tended to engage longer with a person-oriented robot. However, according to the perception of the service experience in our study, the conversations with the person-oriented robot were thought to be too long. People preferred shorter conversations with the task-oriented robot. These findings imply that though people generally spend more time interacting with a person-oriented robot than a task-oriented robot, their perception toward the person-oriented robot is not necessarily better.

Our results showed that the participants always had a better perception of the services provided by the task-oriented robot. The participants would like to follow the instructions, interact and

see a task-oriented Pepper in real life more than a person-oriented robot. This finding suggests that people would better perceive a restaurant reception robot in the task-oriented style. If a restaurant plans to use a robot for the reception work, it might be good to consider designing a robot in a task-oriented style.

A possible reason why the participants perceived the person-oriented robot to be worse could be that it fell into the uncanny valley (Mori, 1970), which is a stage that a humanoid robot is highly human-like but people realize it is not an actual human. The uncanny valley makes people uncomfortable and even provokes a revulsion toward the robot. Therefore, it will be meaningful to explore where the safe level of social interaction is in restaurant environments, which will help improve people's perception of the robot designs and keep them from falling into the uncanny valley.

Moreover, the interaction duration of the designed person-oriented style was longer than the designed task-oriented style in this study due to the extra-added chit-chats. The effect of the different interaction duration on the participants' perception of the styles was omitted. The future work can further investigate how the participants' perception of the service experience is when the total interaction duration remains the same.

6 Overall Conclusion

Firstly, we conducted interviews for restaurant robot requirements. The restaurant employees generally held positive attitudes toward robots and would be willing to work with service robots. From the perspective of restaurant employees, reception work was where they expected the most help from robots, compared to other tasks such as serving. They also suggested that Pepper suited reception work best in restaurants.

Then based on the interview results, our research questions and the COVID-19 measures, we developed a function flow for Pepper to perform the reception tasks in a restaurant. The three main function modules were *Greeting and table management*, *Restaurant history* and *Menu*. We tested the flow with a pilot in the restaurant Lab071, Leiden. The participants included customers and staff. Their general experiences of interacting with Pepper were good. We improved the flow according to their feedback during the pilot, including adding more instructions, refining Pepper's speech processing, etc.

Lastly, we designed task- and person-oriented communication styles on the reception Pepper robot. The task-oriented style was more formal and aiming to finish reception tasks straightforward, and the person-oriented communication style was more informal and chatty. We collected people's perception of Pepper in the two different styles. The results showed that people's perception of the communication orientation and the service experience was significantly affected by the communication styles of Pepper, which meant that people could "distinguish" the communication orientation of the robot and would have a different impression of the reception service provided by the robot in different communication styles. According to the evaluation of the perceived service experience, people showed a higher willingness to be received by a task-oriented robot than a person-oriented robot. However, people's perception of the robot's

characteristics were not significantly affected by the communication styles. The finding suggests that it is possible to manipulate the communication styles of the robot without changing people's impression of the robot's characteristics.

The experiments of this study were conducted online due to the COVID-19 so the participants watched a video instead of communicating with Pepper in practice, which might impact the participants' perception in the experiments. And in this project, we specially designed and evaluated the reception robot in a restaurant environment. Therefore, it would be interesting to conduct studies offline with reception robots in other environments for future work.

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