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DOI
10.1007/978-3-031-31682-1_4

Publication date
2023

Document Version
Final published version

Published in
Digital Transformation of the Hotel Industry

Selecting Robots to Take Over Tasks in Hospitality Settings: Joining Two Research Fields

Klaas Koerten and David Abbink

1 Introduction

Labour shortages in the hospitality industry have dramatically increased as a result of the crisis of the COVID pandemic. To guarantee operations and facilitate work processes, hotels and restaurants are increasingly exploring the potential use of robots, here defined as mechanical devices, powered by artificial intelligence. Because of their increased use, hospitality robotics have also grown in popularity as a research topic. We believe that effective innovation and scientific understanding of the impact of hospitality robots on work processes requires a close transdisciplinary collaboration. With transdisciplinary research, we mean the close integration of interdisciplinary academic research (e.g. robotics, design, social sciences) with knowledge and professional expertise from the hospitality industry, including those of the workers performing physical work processes. Therefore, we have started a transdisciplinary initiative powered by the Hotelschool The Hague (including their Skotel, a hotel that teaches students hospitality work) and the Delft University of Technology (including their innovation field lab RoboHouse). This collaboration, made possible by the Impulse Project, aims to enable experimental research and design towards robot-assisted work processes in the hotel and restaurant environment of the Hotelschool. Findings from observations in hotel environments can be used to guide the selection of relevant work processes and the corresponding design

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J. Marques, R. P. Marques (eds.), *Digital Transformation of the Hotel Industry*, Tourism, Hospitality & Event Management,
https://doi.org/10.1007/978-3-031-31682-1_4

of robot prototypes, and vice versa newly developed robot prototypes can be evaluated immediately in representative hotel environments.

To kick off this new collaboration, we wanted to implement a robot and use it to execute tasks in the hotel environment of the Hotelschool The Hague and perform experiments with it. When selecting this robot and trying to make an overview of scientific literature on hospitality robotics, we noticed a lack of integrated knowledge from the literature. Therefore, in this chapter, we aim to integrate the large body of state-of-the-art literature from both the hospitality world and the robotics research community, around the potential of using commercially available robots and robots under development.

In Sect. 2, we will elaborate on the current state of the art of implemented hospitality robotics, drawing mostly on press publications. In Sect. 3, we review the literature on hospitality robotics: from the robotics community which develops prototypes and from the hospitality research community, which typically focuses on the impact of commercially available robots on guest experience and organisation. In Sect. 4, we present a conceptual framework to use when understanding the potential impact and unforeseen consequences of introducing robot systems in hospitality settings. Section 5 will look at hospitality robotics on a more conceptual level and will discuss the extent of its possibilities. This section also discusses general findings and insights on hospitality robotics.

2 State of the Art of Commercially Available Hospitality Robots

Robots are traditionally used to take over tasks performed by humans and to execute them in a more constant and reliable manner. The first functional robot, the Unimate, was implemented in a car factory, where it had to pick hot cast metal parts from an oven. The main reason for this was the fact that the parts were too hot and too heavy for human workers to handle, resulting in many injuries (Gasparetto and Scalera 2019). Ever since the successful implementation of the Unimate, robots have been implemented to take over various tasks normally executed by human workers. The advantages that robots hold over humans are the following:

1. Robots can work 24 h a day, 7 days a week.
2. Robots work more consistently than humans.
3. Robots can operate in conditions where humans cannot (in a vacuum, in extreme heat or cold).
4. Robots can operate on scales where humans cannot (extreme small microrobotics or large robots for handling items that are too heavy for humans to carry).

Robotics have proven extremely efficient in many production applications. The vast majority of all cars, for example, are nowadays assembled with the help of robots. Because of this usefulness, the application of robotics nowadays stretches far beyond factory environments. The first robot that was available for consumers to buy was a robot vacuum cleaner, which vacuums rooms autonomously. In recent years, robots have also been developed specifically for the field of hospitality, where they are able to take over tasks such as cooking food, operating a reception or transporting items through a hotel. A number of recent publications start off by stating how robots are currently changing the hospitality industry (Belanche et al. 2021; de Kervenoael et al. 2020; Ivanov and Webster 2017, 2019; Nonaka et al. 2020; Vatan and Dogan 2021; Pitardi et al. 2021; Tuomi et al. 2021; Shin and Jeong 2020; Merkle 2019; Pizam et al. 2022). Although it is true that robots are being introduced in hotels and restaurants more often, the range of tasks that are being taken over by them is still rather narrow. There are three main types of robots developed for hotels and restaurants nowadays. Out of those three types, only two are commercially available on a large scale.

2.1 Hospitality Robotics Categories

Type 1: Transportation Robots

The first type is transportation robots. These robots are used in hotels and restaurants to transport items. The COVID pandemic has seen an increase in the use of these robots specifically in restaurant settings for transporting dishes from the kitchen to the restaurant floor and vice versa (Chiang and Trimi 2020). Designs of such robots have been discussed as early as 2007 (Railhet et al. 2007; Jyh-Hwa and Kuo 2008; Qing-xiao et al. 2010). When this research was done, the robot was presented as something to be used inside a robot restaurant. A restaurant like this would serve entertainment purposes. However, nowadays these robots are implemented to deal with labour shortages, which increased due to the COVID pandemic. Studies by Shimmura et al. (2020) and Nonaka et al. (2020) report increased productivity and employee satisfaction when food delivery robots are introduced. The design of these robots comes from automated guided vehicles (AGVs), which are normally used in factories to transport items. Shimmura et al. (2020) also refer to the restaurant robot as an AGV. Examples of transportation robots are the PuduBot and the BellaBot, both shown in Fig. 1. AGVs like this are also used to take over other transportation tasks in hotels. One of these tasks is delivering room service to rooms. Robots developed specifically for this are the Relay and Flashbot. Because they travel through a hotel without supervision of a human worker, they have compartments that can only be opened by the guests for whom the room service is. Relay and Flashbot are shown in the first row of the table in Fig. 1. AGVs are also used for transporting luggage. An example is the TUG robot by the Aethon company, which is usually used in hospitals to transport medical objects (Anna 2018). The TUG also contains a closed-off compartment and is larger and suited to carry heavier loads than restaurant or room service robots. Since the robots are adjusted to fit the task they are used for, their designs vary. Their basic layout, however, is extremely similar. They all share the following properties:

Category	Examples	Characteristics	Task Specification
Transportation Robots	 TUG Pudubot Relay Flashbot Bellabot	- Movement on wheels - Transporting objects - Guest interaction optional	- Transportation - Physical load reduction
Reception Robots	 Pepper Temi Sanbot Alice Cruzr	- Movement on wheels - Providing information - Tablet interface - Arms for gestures - Guest interaction	- Information exchange - Emotional stimulation
Food Preparation Robots	 Spyce Creator Pazzi	- Stationary - Multiple physical tasks - Different application for differnt meals - No guest interaction	- Manipulation

Fig. 1 Overview of the current state of functional hospitality robotics. The three categories are (1) transportation robots, (2) reception robots and (3) food preparation robots. Each category executes tasks from specific categories, as described in Onnasch and Roesler (2021)

1. The robots transport items.
2. The robots move on wheels over flat surfaces.
3. The task and design depends on the items the robot needs to transport.

Type 2: Reception Robots

The second type of hospitality robotics is robots that take over typical reception tasks. We refer to these robots as reception robots. The robots consist of a user interface that interacts with guests. This user interface can consist of a tablet or a speech recognition and production system or a combination of the two. This interface is mounted on a kart so that the robot can move over flat surfaces. Examples of these robots are the Pepper, Temi, Sanbot, Alice and Cruzr robot, all displayed in the second row of Fig. 1. The robots differ in physical complexity. For example, the Temi robot only contains a tablet that can navigate itself, while the Pepper robot is designed to look like a caricaturised human that has an actual face and arms that can move to support the sound that it outputs and make the robot look more human-like. The only physical task that these robots perform is that of navigating a room. The robots can therefore be used to show people around. The main tasks that these robots can execute lie in the category of information exchange (Onnasch and Roesler

2021). This means that the robots provide users with information via either images shown on their tablet or spoken language. These robots are also able to communicate with software systems and are therefore able to make (video) calls, check people in or look up information on the Internet. The development of these robots comes from the current development of chatbots and AI applications that are able to understand and process natural language. Reception robots all share the following characteristics:

1. The only physical task that the robots execute is moving themselves around on wheels.
2. The tasks consist mostly of interacting with humans through speech or tablet interfaces.
3. The robots have a humanoid appearance.
4. The robots are designed to interact with guests.

Type 3: Food Preparation Robots
The third type of robots is used for food preparation. Examples include the Pazzi restaurant that prepares, cooks and sells pizzas without human cooks, the automatic stir-fry machines from the Spyce Kitchen restaurant and the Burger production robot by the company Creator. These applications all focus on transforming raw ingredients into finished meals and the aforementioned examples can be seen in the bottom row of Fig. 1. Examples of food preparation robots can be found as early as 2007 (Yan et al. 2007). The structures of these robots differ greatly. This is because the preparation of different meals requires different tasks and therefore the robotic solutions also differ. The Pazzi kitchen executes tasks such as flattening pizza dough, applying sauce and toppings and shoving a pizza into an oven, baking it and taking it out (Ware 2021). The robotic stir-fry pans from the Spyce restaurant fry ingredients that are put into them and then empty the fried ingredients onto a plate (Albrecht 2020). Often, these robots execute a variety of tasks. For example, the stir-fry robot from Spyce also cleans the pans after a meal has been cooked in them. However, it does not deliver a finished meal; thus, additional toppings need to be added by a human cook. The Pazzi kitchen does finish completely finished pizzas, but it does not clean itself. The Creator burger robot cuts its own ingredients, which is something that neither the Spyce nor the Pazzi do (Troitino 2018). While the tasks of these robots differ greatly, we have still put them into the same category. This is because they all share the following high-level traits:

1. The robots operate in a fixed place.
2. The robots take over one or more task in the cooking process.
3. The robots can only cook a limited amount of dishes.
4. The robots increase productivity.

Food preparation robots are ill suited for restaurants and hotels that change their menu frequently because of the limited amount of dishes that they can autonomously make. Because of this, the use of these robots is limited to specific types of restaurants. They all operate in restaurants with some sort of fast food business model. The robots also do not work in close interaction with human employees.

Looking at the examples as a whole, they serve more as production machines or little factories than as interactive robots. An exception to this trend is Flippy, a robotic arm by Miso Robotics that can deep fry food and grill burgers. There was one case of a restaurant that implemented Flippy, but the robot worked so fast that the employees had to switch it off from time to time in order to not get overloaded with burgers and fries. The designers of the robot needed to do a technical iteration to fix this issue (Kooser 2021).

2.2 *Insights on Commercially Implemented Hospitality Robotics*

Although each type of hospitality robot is different, they do share properties that shed light on the overall concept of hospitality robotics. First of all, it has been shown that robots generally get designed for specific tasks. This is also confirmed by Osawa et al. (2017). When tasks are taken over from human employees, robots are able to execute the tasks for longer periods of time without pause. Robots also deliver a more constant quality. This is the main advantage that robots hold over humans. This property can, however, also be seen as their main disadvantage. Robots do not possess the flexibility that humans do. Where humans are able to take over tasks from one another, robots cannot execute tasks outside of what they were designed for. It would seem logical that hospitality robots only bring improvement when there is enough work for them to do. This means that in smaller hotels or restaurants, where less employees execute the entire variety of hotel and restaurant tasks, robots would be much less effective than in large-scale hospitality venues. The known examples of implemented hospitality robotics also underline this statement. The two studies that have shown the improved production resulting from the implementation of food delivery robots were both conducted in restaurants with more than 150 tables (Nonaka et al. 2020; Shimmura et al. 2020). The food preparation robots also show this. The examples that were shown in the previous section are all from some sort of fast food restaurant, where the robots are used to deliver very similar, standardised meals as fast as possible, with a constant quality.

Another interesting thing to mention is the interaction of robots with guests. Traditionally, robots only needed to interact with workers of the organisations that implemented them. When workers interact with robots, the interaction might be awkward at the beginning. However, employees can be trained to operate the robot properly, and when the interaction is difficult or causes problems, employees can report feedback to their managers, hoping that this will be solved. For robots interacting with guests, it is a different story. Guests do not generally do not get prepared before interacting with a robot. They also do not need to submit feedback after interacting with one. When guests have had a bad interaction with a robot, they can choose just not to return to the venue. Because of this, the interaction between the robot and guest needs to be carefully designed and not be unpleasant for the guests. Furthermore, there is a large difference in guests' attitudes towards robots (Ayyildiz et al. 2022). Some guests like interacting with new technology and some guests don't. The food preparation robots that were described do not have much guest interaction. In some cases, guests can choose what they want from the food preparation robot, but from a high level, the robot serves as a sophisticated vending machine. With reception robots, there is almost always a robot–guest interaction, since the robot communicates with the guest. For the food delivery robots, it is optional for the organisation that implements them to use robot–guest interaction. Some restaurants let their robots drive up to the table where guests can take their plates off of them. In other cases, the robot drives to a fixed station, where an employee takes items to do the serving part.

What also needs to be considered is the gimmick or novelty effect that robots can have. For some guests, new technology is interesting, which makes robots have a positive effect on them. Having a robot implemented can also draw new interested guests to environment that they are implemented in. That is why the Spyce restaurant, the Creator burger robot and the Pazzi pizza robot display their robots for their guests to see. The long-term benefit that robots have on operations therefore only becomes clear after this effect has worn off.

3 Scientific Literature on Hospitality Robotics

As hospitality robots get implemented more, they are also more heavily researched. We have found that the current body of literature on hospitality robotics can be roughly divided into two categories corresponding to two traditional research fields. These are the field of robotics and the field of hospitality. The robotics side is concerned with designs and development of new robots as well as evaluating them in terms of efficiency and task execution. The hospitality side is concerned with how implemented robotics influence traditional hospitality.

3.1 Robotics Research on Hospitality Robotics

Hospitality robotics studies from the field of robotics mostly present a novel design of a robot or robot software. Because there is a large variety of tasks in hotels (this will be further discussed in Sect. 5), there is also a large variety in the designs of novel hospitality robotics. Designs consider robots that provide guests with information (Pinillos et al. 2016; Ahn et al. 2019), robots specialised in cooking (Sugiura et al. 2011; Yan et al. 2007), robots that recognise nonverbal cues from guests (Gaschler et al. 2012), robots that can set and clear tables (Acosta et al. 2006) and robots for serving items (Hoang and Tran 2022; Jyh-Hwa and Kuo 2008; Hung et al. 2021). However well designed, the majority of these hospitality robots do not get tested in actual hotel environments. These studies often focus on increased productivity or efficiency that robots bring, but not on the experience of the employees or the guests that will need to interact with the robot. Gaschler et al. (2012) and Acosta et al. (2006), for example, report the accuracy of the robot being able to recognise nonverbal cues from guests and being able to identify cutlery on a table, respectively. The guest or employee experience of interacting with the robot is not evaluated. Also, these examples are evaluated in a lab environment, not in an actual hotel setting with employees and guests.

In determining the success of the robot, the focus lies on organisational benefits. With organisational benefits, we refer to benefits that are of interest to the organisation such as increased efficiency, reduced costs, etc. In the field of robotics, it is logical for researchers to report on these factors, as in traditional industrial robotic applications, these things determine the success of the robot. However, in hospitality settings, as was discussed in the previous section, robots take over specific tasks, which mean that they will inevitably need to interact with human employees. The robots will also have an effect on guest experience, either directly because the robots interact with guests or indirectly, because the tasks of the employees that interact with the guests have been changed. However, as the majority of the robotics studies present novel designs, these studies only contain small evaluations of the robot that are done by the designers most of the time.

Hospitality researchers state that for realistic evaluation of hospitality robotics, novel robots need to be tested in a representative hotel environment (Tuomi et al. 2021). Robotics studies that have done this are Pinillos et al. z2016) and Ahn et al. (2019). Ahn et al. (2019) discuss the development of a robot concierge that answers questions from guests during a conference. The study stresses that when implementing the robot in a hotel lobby, numerous problems were encountered that are normally not discussed in academic research. Something similar is reported by Pinillos et al. (2016), which evaluates the implementation of Sacarino, a robotic bell boy, of which the design is discussed in Zalama et al. (2014). The robot was implemented in the lobby of a hotel in Spain for several weeks where it executed a number of tasks normally left to the hotel staff. This study is highly technical as well (the robot's success is expressed in terms of hours that it was active and how many tasks it executed 'correctly', without stating what correctly means). However, Pinillos et al. (2016) underline the importance of design iteration, meaning that, however well designed, after some amount of time being operational at a hotel, the designers of Sacarino found that there were flaws in the robot's design. They made an iteration, trying to update the robot so that it would no longer exert these flaws. After the update, the robot was used much more often and showed improvement in the metrics that were used to evaluate task execution. This study shows that successful implementation of a robot will most likely take time and one or more design iterations. By careful design and a hotel environment suited for the robot, but also by collecting data and iterating the design on the findings from that data, a much more realistic image of the efficacy of novel hospitality robots can be presented.

3.2 Hospitality Research on Hospitality Robotics

The second type of hospitality robotics research is from the field of hospitality. Studies from this field mostly evaluate robots that are already commercially available, and the focus is on the experiences that guests and employees have with interacting with these robots. However, hospitality researchers often lack technical knowledge, and therefore, the more technical aspects of robotics are not studied. For example, a number of studies solely focus on the attitudes of hotel employees or guests towards robots. Examples are Choi et al. (2020), Vatan and Dogan (2021), Pizam et al. (2022) and Piçarra et al. (2016). In these studies, hotel managers, employees, or guests get interviewed on their perception of robots. These studies all result in similar conclusions, namely, that service of human employees is rewarded higher than that of robots and that humans are better in communicating with guests (Choi et al. 2020; Vatan and Dogan 2021) and that the presumed capabilities of a robot correlate with people's eagerness to use them (Pizam et al. 2022; Piçarra et al. 2016). There are also a number of studies that research the difference between robots and humans executing tasks in hotels and finding differences in guests' perceptions of this. Examples of studies that do so are Choi et al. (2020), Hoang and Tran (2022), Kim et al. (2021) and Shin and Jeong (2020). However, these studies work with questionnaires where participants are only provided with images of the human employee and the robot and they need to imagine the interaction themselves. These studies conclude with statements on whether guests deem robots or humans better at certain service tasks. The literature reviews by Shin (2022) and Ivanov et al. (2019) give an overview of current hospitality robotics research from the hospitality field. The different studies are classified based on which stakeholder the robot interacts with. The four stakeholders are guests, employees, the hotel organisation and society. Shin (2022) continues by presenting 28 research questions stemming from the available literature that are still unanswered. This study states that many of those questions can be answered by studying actual implemented robotics in real-world scenarios.

As with research from the robotics field, there are a few exceptions that evaluate the efficacy of commercially available robots in actual hotel environments. Examples are Shimmura et al. (2020), Nonaka et al. (2020), Seyitoğlu and Ivanov (2020) and Odekerken-Schröder et al. (2021). All three of which study food delivery robots implemented in restaurants. The findings of Shimmura et al. (2020) and Nonaka et al. (2020) are that food delivery robots improve productivity in a large-scale restaurant. Odekerken-Schröder et al. (2021) focus on how food delivery robots are perceived by guests. These studies show that to understand guests' and employees' experience with hospitality robotics, actual implemented robotics need to be studied.

3.3 Insights on the Scientific Literature on Hospitality and Robotics

The main finding from this section is the dichotomy between the robotics field and the hospitality field in scientific literature. Robotics researchers lack knowledge on guest experience and hospitality researchers lack technical knowledge on robot implementation. As a result of this, most of the studies that are mentioned in this section have not studied robots in actual hotel environments. To study the complete impact and possibilities of hospitality robotics, the knowledge of these fields needs to be joined. The few studies that did study robots in a hospitality environment provide us with knowledge that correct implementation of novel hospitality robotics takes time and some iteration. The studies by Shimmura et al. (2020), Nonaka et al. (2020) and Odekerken-Schröder et al. (2021) furthermore show that implementation of restaurant robots can have a positive effect on sales, employee satisfaction and guest satisfaction. However, there is no study that has evaluated the effect of robotics on all three of these factors and there are no similar studies on robots other than food delivery robots.

4 Interaction Models

We explain the distinction between the fields of robotics and hospitality based on the different interactions in these organisations that the robot influences when it is implemented. Figure 2 shows simplified interaction diagrams of an industrial work environment with robots (left) and a hospitality work environment without robots (right). The left part of the figure shows the three stakeholders: the organisation (top), the robot(s) (left) and the pool of employees (right). The dotted lines in this diagram represent interactions between the stakeholders. The interaction between the robot and the organisation is an abstract one. It encompasses the organisation

Fig. 2 Conceptual framework of the stakeholders for the robotics field as well as the hospitality research field. The figure on the left shows the main stakeholders in a traditional work environment with robots, namely, the robots, the employees and the organisation. The figure on the right shows the main stakeholders in a hospitality work environment: the guests, the employees and the organisation

choosing for implementing the robot and the robot, when implemented, having an influence on production and efficiency, and therefore influencing the organisation positively or negatively. The interaction between the employees and the robot is much more direct. Since robots take over certain tasks that used to be human tasks, the employees need to operate and monitor the robot. In robotics research, these two interactions are the most important. If a robot does not benefit an organisation, there is no reason for it to get used, so the robot needs to have clear organisational benefits. At the same time, the robot needs to be operated by workers, so designing this interaction well is important for the successful implementation of a robot. The interaction line between the employees and the organisation is also influenced by the robot when it enters the work environment. This happens as the robot takes over tasks, thereby changing the job of the human employees. The job of the employees might improve, making them happier, or it could become less interesting, making workers less happy. The result can also be twofold. For example, when a robot takes over tasks and therefore makes one or more human workers obsolete, the impact is negative for the employee(s) that are being let go. But the remaining tasks could result in more interesting and rewarding jobs for the remaining employees. Also, as an organisation implements robots, there might become new jobs available such as maintenance jobs to keep the robot operational.

We use a similar interaction diagram to represent hospitality work environments on the right side of Fig. 2. Here the stakeholders are the organisation (top), the guests (left) and the employees (right). In this interaction diagram, each stakeholder has certain needs. The guests need to be treated hospitably. This means the employees execute tasks to give the guest the best possible experience. The guest in return patronises the hospitality organisation by spending money. A more enjoyable guest experience can result in the guest returning to the same venue and spending more, which keeps the organisation running. The organisation pays the employees salary to have them execute tasks to satisfy the guests. However, the employees should not merely be viewed as people that execute tasks for a salary. Employees experience stress during their job and this should be kept to a minimum. Bakker (2011) states that as employees are more engaged into their job, they feel motivated and needed. This is also stated in the JD-R model by Bakker and Demerouti (2007), which states that organisations put certain demands on their employees, meaning that they expect some sort of work to be done. Employees have job resources, referring to the energy and time they have to do work. The JD-R model states that certain types of work deplete workers of their resources, but that tasks that make employees engaged in their work, that make them feel valued and feel like they play a valuable role in an organisation, not deplete but increase job resources. This is also underlined specifically for hospitality organisations by Yang (2010), which found that as hotel employees have more social contact, autonomy and engagement, their job satisfaction is increased and employee turnover is reduced. It is thus desirable for hospitality organisations to keep their employees satisfied. We refer to this type of satisfaction as eudaimonic happiness (Delle Fave et al. 2011), which is also referred to as long time happiness and refers to people feeling fulfilled and needed in life. This eudaimonic happiness differs greatly from hedonic happiness. Hedonic happiness

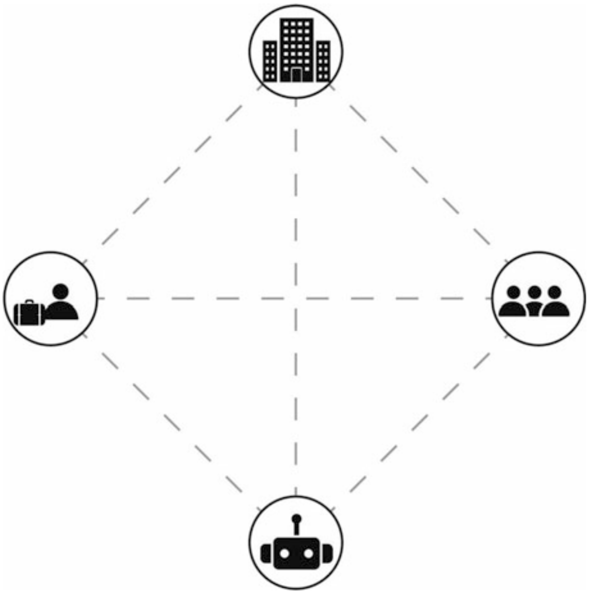

Fig. 3 A conceptual framework to indicate possible impacts of introducing a robot (bottom icon) into a hospitality environment, consisting of the organisation (top), the guest(s) (left) and the employee(s). The dashed line might be replaced by an arrow from one element to the other, denoting a positive or negative impact (hypothesised or empirically observed). Note that this representation highlights that the introduction of the robots might have different impacts on guests, employees and organisations, and even on how the upper triangle is organised (e.g. how employees interact with guests, the kind of jobs the organisation can offer its employees, etc.)

refers to things that give direct pleasure but do not necessarily contribute to long-term happiness goals. This hedonic happiness is typically what guests expect in a hotel, in the form of hospitable treatment, quality food and drinks and a comfortable bed.

To make an interaction diagram that illustrates a hospitality organisation with robots in them, the two aforementioned diagrams need to be combined, resulting in the diagram from Fig. 3. There is only one new line, which is the one between the robot and the guest, something that has been touched upon in the previous section. However, this model also gives insight on how the different stakeholders have become connected via each other. Because of this, interactions can influence different stakeholders indirectly. We want to show how this interaction diagram can be used for analysing actual use cases of hospitality robotics by looking at two specific cases. Both cases are about food delivery robots in restaurants. The first case has implemented restaurant robots implemented correctly and the second one incorrectly.

4.1 Food Delivery Robots Implemented Correctly

The first case study comes from a Japanese restaurant that implemented food delivery robots. The efficacy of these robots is evaluated in Shimmura et al. (2020) and Nonaka et al. (2020). Both papers discuss the same restaurant with food delivery robots installed. The restaurant has 441 tables and four robots are implemented. The robots are customised to match the interior of the restaurant as to not stand out. The robots do not interact with guests, only with employees who take the food from the robots and serve it at the tables. The study by Shimmura et al. (2020) reports increased sales per hour after the robots were introduced. Nonaka et al. (2020) report increased employee happiness, mostly because waiters needed to make runs to the kitchen less often after the robots got installed. An interaction diagram is made of this case study and can be seen in Fig. 4.

This diagram shows a positive interaction of the organisation on the robot, representing the organisation employing the robot (line 1). The robot only interacts with employees, and since the employees enjoy the fact that they need to run to the kitchen less often, this interaction is also positive (line 2). We hypothesise that because of this, employees have more time to interact with guests, which increases their hedonic happiness (line 3), resulting in higher sales, which is a positive interaction with the organisation (line 4). Employees that have more time for the parts of their jobs that they enjoy have increased eudaimonic happiness, which in general causes less strain and turnover (Yan et al. 2007), which benefits the organisation employing them (line 5).

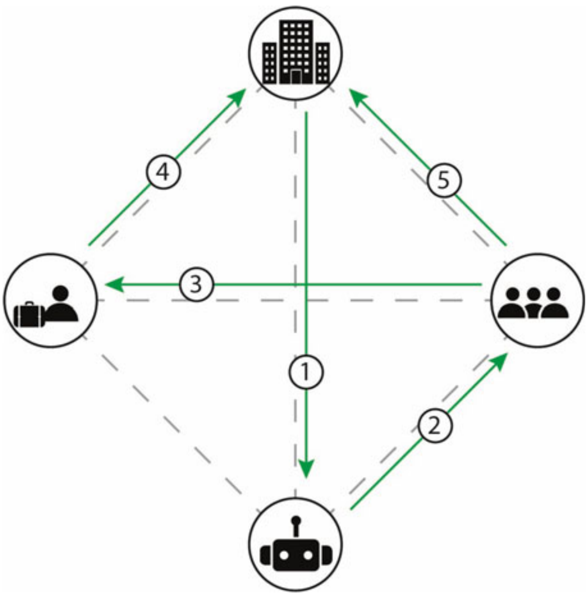

Fig. 4 Interaction lines influenced by a restaurant robot. (1) The organisation implements the robot to transport items from the kitchen to the restaurant floor. (2) The employees need to head to the kitchen less often for items, increasing their eudaimonic value. (3) The employees have more time to engage with guests, increasing the guests' satisfaction and their hedonistic happiness. (4) The guests decide to return to the restaurant more often. (5) Increased job satisfaction makes less employees quit

4.2 *Food Delivery Robots Implemented Incorrectly*

The second case study comes from Seyitoğlu and Ivanov (2020). This study evaluates 582 online reviews of restaurants with robots employed. Most of the reviews are positive of robots in restaurants, and many of the reviewers went to a robot restaurant specifically to experience robots. However, in one of the restaurants, robots sometimes deliver items to the wrong tables. When this happens, employees need to step in to fix these problems. Reviews about this situation state that guests don't enjoy this. An interaction diagram of this situation is shown in Fig. 5. Here there also is a positive interaction of the organisation implementing the robot (line 1). The robot decreases the guests' hedonic pleasure by delivering wrong items (line 2). Because human employees need to step in and fix the problems, they experience less eudaimonic pleasure (line 3). Workers having less time for the guests because they need to fix the robot's mistake also decrease hedonic pleasure of the guests (line 4), which could cause reduced sales (line 5). Finally, less happy employees affect the organisation negatively (line 6).

These are just two examples in which a robot introduced in a restaurant environment can influence all the stakeholders, directly or indirectly, positively or negatively. This model shows how all stakeholders are connected in a hospitality work

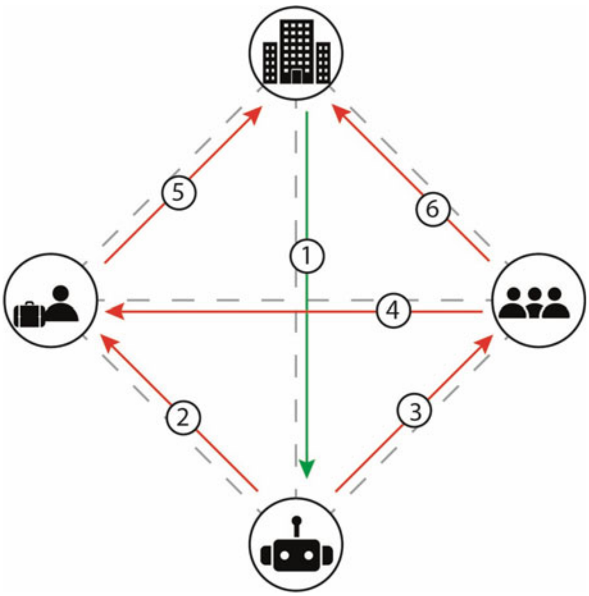

Fig. 5 Interaction lines influenced by a restaurant robot. (1) The organisation implements the robot to transport items from the kitchen to the restaurant floor. (2) The robot delivers wrong items to guests, reducing their satisfaction and hedonistic happiness. (3) Employees need to step in to fix the issue with the robot, reducing their eudaimonic job happiness. (4) The employees have less time for the guests, lowering the guests' hedonistic happiness. (5) The dissatisfaction of the guests results in them not returning to the restaurant. (6) Less happy employees cause more of them to quit

environment with robots. It can therefore be used as a guide to predict the full effect that implementing a robot might have on a hospitality work environment and it might assist the implementation of hospitality robots. We want to state that for each different task, the diagram might look different and that for many task, this diagram could also be too limited. There might be more stakeholders or more complex interactions. Consider, for example, the case where a robot relieves employees of repetitive work to such an extent that one employee is let go. In this case, the fired employee is affected negatively, while the remaining employees experience increased job satisfaction. For analysing such cases, more detailed interaction diagrams could be needed. Although limited in some cases, this way of looking at hospitality robotics via interactions can predict a lot about the full effect that a robot has on a hospitality work environment.

5 The Bigger Picture

We have tried to give an overview of the current state of hospitality robotics, in terms of applications that are available today as where the current research stands. This section will elaborate on the possible extent of hospitality robotics in the future. We will explain how robots could affect hotel organisations, employees and guests.

5.1 Robotising Tasks

As robots are designed to take over tasks from humans, the amount of hospitality robots that can be developed lies in the same range as the amount of tasks present at a hotel. It is therefore insightful to find out all physical tasks present in a hotel. We have made a list of these tasks which can be seen in Table 1. We have made two distinctions when setting up this list. The first one is the distinction between food and beverages (F&B) and room division and reception (RD). This is a traditional distinction made in hotel management. This distinction was made because the vast majority of jobs in a hotel fall in either one of these categories. The other distinction was made on whether the task had guest interaction or no guest interaction. This distinction was made from a robot development perspective. As was mentioned earlier, a robot that has interaction with guests requires a far more elaborated design, because the interaction needs to work from the start. The resulting list of tasks contains four categories. The list has been checked by F&B and RD experts at the Hotelschool The Hague to make sure that there were no major tasks missing. The resulting list consists of 38 tasks. Such a list gives insight in how many hospitality robots could theoretically be developed to robotise work in hotels further.

As was stated in Sect. 2 and in Fig. 1, the currently available robots deal with one or more task categories from Onnasch and Roesler (2021), which gives an overview

Table 1 Tasks in a hotel

	Food and beverages	Room division and reception
Guest interaction	• Welcoming guests • Checking reservations • Showing guests to their table • Taking orders • Serving food • Inquiring about service • Making drinks • Handling payment • Collecting dirty dishes • Transporting dishes • *Mise en place* • Operating cash register	• Welcoming guests • Checking in guests • Taking luggage from guests • Providing information, handling requests • Answering room service requests • Serving room service • Checking out, including payment
No guest interaction	• Gathering ingredients • Preparing ingredients for cooking • Cooking food • Plating • Making drinks • Cleaning up kitchen and floor • Cleaning dishes • Cleaning floors • Collect orders from storage • Cleaning kitchen machines	• Vacuuming floors • Changing beds • Cleaning furniture • Cleaning bathroom and toilets • Tidying up • Restocking items in room • Preparing room service • Transporting luggage to room • Dividing and distributing laundry

of human–robot interactions. The eight task categories that robots can execute presented in this paper are:

1. Information exchange
2. Precision
3. Physical load reduction
4. Transport
5. Manipulation
6. Cognitive stimulation
7. Emotional stimulation
8. Physical stimulation

Looking at this list and at the list of hotel tasks, we can see that certain task categories are not present in hotels. The categories precision, cognitive stimulation and physical stimulation are not tasks that are normally executed by human workers in a hotel. Precision refers to robots taking over tasks that are too precise to execute for humans. Cognitive stimulation refers to tasks meant to engage a human and teaching him or her something. Physical stimulation refers to tasks interacting with somebody physically (Onnasch and Roesler 2021).

5.2 The Difference Between Human and Robot Tasks

It is important to note that what is perceived as one task for a human could consist of a number of tasks for a robot. For example, clearing a table where guests have had diner is no difficult challenge for a human waiter. It consists of picking up the items on a table and putting them on a trolley or carrying them to the kitchen. If a robot would have to do this, it would need a number of advanced technical capabilities. First of all, it would need a sensor system that is able to identify the various items on the table. It would need some sort of arm that can reach towards the items. Then it needs a gripper to pick up the variety of items without damaging them. Next, it would need to stack the items on a trolley so that it can be transported to the kitchen. Building a robot like this comes with new challenges. The robot needs to identify the items during different times of the day (meaning different levels of sunlight, affecting camera systems). The arm needs to extend all the way across the table. The arm needs to reach the items that could be spread over the table in a number of positions. The gripper needs to be able to pick up a plate, as well as a wine glass and a piece of cutlery, which are very different items. These are difficult things to build and when a robot like this would be functional, the question remains if it is faster than a human waiter. Acosta et al. (2006) present the design of a table clearing robot, explaining exactly these challenges. The task of clearing a table is divided into different tasks: identifying the table to be cleared in a restaurant, recognising the objects on the table and picking up these objects. This study's aim is to design a robot that can set and clear tables in a controlled environment. The final prototype takes 8 s to identify eight pieces of cutlery, and when clearing two tables in a restaurant without people present, it only picks up 83% of the items it is supposed to collect. It should be noted that this study is a good start in the direction of designing robots for these types of tasks, but we were not able to find a publication that designs a similar robot in the publications that referenced Acosta et al. (2006), meaning that this research line has not been continued.

We assume that the current examples of hospitality robotics might be the result of robotising the tasks in a hotel that are easiest to automate. The physical structures of delivery robots and reception robots are relatively simple. A delivery robot is an electric wheeled vehicle and a reception robot is similar, but on top of that, it contains a tablet interface, speakers and a microphone and sometimes a face and arms for gestures. The food preparation robots have much more complicated structures, but in their case, these structures are located in one place in the hotel and closed off from guests, which ensures these structures don't interact with guests physically. The food preparation robots therefore act more like advanced vending machines than like interactive robots, and they don't have the challenges of navigation and guest interaction that the transportation and reception robots have. The table clearing robot from Acosta et al. (2006) is already much more complicated than a transportation robot, because the structure for picking up items is mounted on something similar to a transportation robot. The example from Acosta et al. (2006)

illustrates how difficult it is to make a robot that can take over certain more difficult tasks from human employees.

5.3 Robots and the Infrastructure in Which They Operate

In some cases, for robots to be able to take over tasks from humans, some difficulty can be taken away by adapting the infrastructure in which humans or robots operate. The infrastructure in hotels is often designed to be optimal for humans to work in. Adapting these infrastructures to robots can make implementing robotics much more easy. A simple task such as opening a door, for example, is an easy task for a human, but for a robot, grasping a door handle, applying the right amount of force in the right direction and then pulling or pushing open the door becomes a very complex series of tasks. Adapting the doors so that they swing open when the robot is near, or when the robot sends a certain signal to the door lock, makes it much easier for a robot to get implemented effectively in a hotel. The same goes for robots that need to an elevator to move from floor to floor. Pushing an elevator button is difficult for a robot. It needs to identify the button and then move a mechanical finger to it to apply the right amount of pressure to it. An elevator button can be regarded as an interface that makes it possible for a human to send a signal into an elevator control system. So if a robot needs to be able to use an elevator, it would be much more convenient if it could send a signal directly to the elevator instead of it having to go through the button interface that was designed specifically for humans. Another example where adapting the infrastructure is important are robots that navigate through hotels. If the floor of a restaurant contains steps or staircases, a robot on wheels becomes unusable. It is much more difficult to design a robot that can walk on steps than one that drives on a flat floor. So making the floor flat and adding ramps where necessary makes implementation of transportation robots much easier. Looking back at the example of robots clearing tables, identifying cutlery and plates correctly can be made possible by attaching electric identifiers to these objects. In doing this, the robot does not need to identify the objects on the table though the visual way, which works well for humans but contains errors for robots.

In this section, we have tried to illustrate the range of tasks in hotels and therefore the range of possible future hospitality robots. We have also presented some general insights on hospitality robotics and robotics in general. We assume that the next tasks to get automated will be the ones with the easiest and most readily available technology. We finally want to state that some tasks that are easy for humans are extremely difficult for robots and vice versa and that sometimes slight changes to infrastructure can make successful implementation of a hospitality robot much more easy.

6 Discussion

In this chapter, we have tried to give an overview of hospitality robotics by highlighting the current state of implemented robots, the state of the academic research, a new model to predict the impact that a robot can have on a hospitality organisation and a view on the near future of hospitality robotics. Looking at news articles and publications, we see that more robotic applications for the hospitality industry have been developed in recent years. At the same time, the amount of tasks that are being automated is still fairly limited and the examples can be divided in as little as three broad categories.

The scientific literature reviewed here furthermore shows the gap between hospitality research and robotics research, and how researchers have great understanding of the field they are in, and limited understanding of the field they are not in. Studies from the hospitality field seem to lack technical expertise and sometimes make conclusive statements on robotics without the participants having even seen one in action. At the same time, studies from the field of robotics are highly technical and performance, but seldom focus on the guest or its experience at all (Acosta et al. 2006) and do not test the developed robot in an environment that is representative of the real world (Gaschler et al. 2012). Pinillos et al. (2016) show us how difficult and time consuming implementing a robot actually is. It explains how an implemented robot initially encounters all sorts of unforeseen errors and that an updated design can fix many of these technical shortcomings. For successful implementation of hospitality robotics, guest–robot interactions need to be designed that optimise both the capabilities of robots and humans and that satisfy the needs of the guest as well as those of the employees.

We advocate that the impact of novel robotic solutions should be investigated from a transdisciplinary perspective in order to expose how the relationships between guest, employees and organisations may change, as a function of how the robot operates in an organisation as a whole. We propose a conceptual framework to illustrate the potentially affected interactions in Figs. 3, 4 and 5. Implementing a robot in a hotel or restaurant will inevitably influence more than one interaction line; even the interactions not directly connected to the robot can be affected. We want to emphasise that when introducing robots in hotels, all the interactions between the different stakeholders in hotels need to be considered. We propose this integrated interaction model to bridge the gap between robotics and hospitality research and to be able to anticipate the far-stretching consequences that implementing hospitality robots may have. We argue that technical expertise and experimentation must be complementary to the understanding of the social context and impacts of the use of robots in hotels. This combined approach must ensure that beneficial effects of robotisation are fully explored, while interactions with humans can be understood and anticipated. When hospitality experts and robotics experts join hands and share their knowledge in transdisciplinary design processes, the possibility is created to create human–robot interactions that can be evaluated using experiments with actual robots in a representative environment that study the benefits of robots while also remaining focused on the guest and employee experience.

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