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Hospitality robotics: Analysing and predicting impact via interaction diagrams

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Abstract
Two of the most pressing issues in hospitality are personnel shortages and high employee turnover. Because of this, the industry looks at robotics as a means to take over tasks, thereby reducing the number of human employees necessary to run a hotel. However, the amount of tasks that can easily be automated is limited. At the same time, it is difficult to design new automated solutions, because the research on the subject of hospitality robotics is disjointed. In this article, an interaction framework is presented that illustrates which interactions are at play when robots take over tasks in hotels and restaurants. A case study is used to illustrate how easily things can go awry and how critical correct implementation is for getting robotics to work properly. For successful implementation of robotic solutions in hospitality, knowledge from different fields needs to be combined along with physical tests of robots in representative environments with consideration of the different stakeholders.

Keywords: Hospitality Robotics, Human Robot Interaction, Interaction Model, Interdisciplinary, Trans-disciplinary

Type: Article

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1. Introduction

Two of the most pressing problems that hospitality faces today are the personnel shortages with over 97% of hotel managers now reporting shortages (AHLA, 2022) and high staff turnover (Djajasinga et al., 2021). Labour shortages in the hospitality industry have dramatically increased as a result of the COVID pandemic (Liu-Lastres et al., 2022). To guarantee operations and facilitate work processes, hotels and restaurants are increasingly exploring the potential use of automation in general and robots specifically (Ayyildiz et al., 2022; Webster, 2021), here defined as mechanical devices, powered by artificial intelligence. These hospitality robotics are gaining increased popularity in restaurants and hotels (Kuo et al., 2017). Because of their increased use and novelty in the field of hospitality, robotics have also grown in popularity as a research topic (Ivanov et al., 2019). As hospitality robotics operate on the cross section of the fields of hospitality and robotics, they can be studied from either one of these fields. Section 2 will discuss the current state of robots in hotels and restaurants, as well as the various recent publications on hospitality robotics from both fields. Making successful use of robots in hospitality requires knowledge from both domains, and could even touch upon other scientific fields, such as Human Resources Management. The authors believe that effective innovation and scientific understanding of the impact of hospitality robots on work processes requires a close trans-disciplinary collaboration, meaning 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. This would then enable experimental research and design towards robot-assisted work processes in real or simulated hotel and restaurant environments. Findings from observations in these environments can be used to guide the selection of relevant work processes and the corresponding design of novel robot prototypes, and vice versa newly developed robot prototypes can be evaluated immediately in representative hotel environments. To bridge the gap that currently exists between traditional scientific fields, an interaction diagrams is presented in section 3. To show how situations with hospitality robots can be analysed with such interaction models, two actual cases of implemented robotics are discussed in section 4. Limitations and benefits of these proposed interaction diagrams are elaborated on in section 5.

2. Background

2.1. Background on Hospitality Problems

The staff shortages that hotels and restaurants are facing today result in hospitality venues not being able to work at their full capacity. The high staff turnover rates furthermore mean that hospitality managers need to spend more time attracting and training new personnel. Morosan and Bowen (2022) state how the Covid pandemic has hit the hospitality sector harder than other industries because hospitality depends on guests being physically present, which was largely prohibited during the pandemic. The amount of people employed in hospitality in the US dropped with 3.65 million between 2019 and 2020 (Bureau of Labour Statistics, 2022). The amount of people working in hospitality has increased again by 2 million since 2020, but there is still a large number of former hospitality employees that do not wish to return to the industry. Sperance (2021) states that the hospitality industry has a reputation of low wages and long hours. Also, the Covid crisis has shown how easily people working in hospitality can be laid off. Most hotels and restaurants are now in a complex situation where the losses from the pandemic need to be regained, but to attract employees, higher wages need to be paid (Sperance, 2021).

2.2. Background on Robotics

In a number of recent publications, robots are being presented as a solution to the aforementioned problems. Robots are complex machines with a higher level of autonomy and flexibility than regular machines that can take over tasks, thereby reducing the amount of employees needed to operate a hotel. Robots are traditionally implemented in industrial manufacturing processes to take over tasks performed by humans and to execute them in a more constant, safe or reliable manner. The first ever 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 high numbers of 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. Some of the advantages that robots hold over humans are:

1. Robots can work 24 hours 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 robots can execute tasks that are too precise for human workers while large robots able to handle items that are too heavy for humans to carry).

Robots also have a number of disadvantages compared to humans:

1. Robots are programmed for specific, limited tasks
2. Robots must be programmed clearly; they cannot understand hidden meanings or deal with ambiguities
3. Robots require specialists to be implemented
4. Robots cannot think creatively or outside of the scope of their tasks

Robotics have proven extremely efficient in many industrial production applications. The vast majority of all cars, for example, are nowadays assembled with the help of robots (Brogårdh, 2007). Because of this usefulness in manufacturing, the automation of tasks using robotics is also being applied in other domains. Robots operating outside manufacturing industry are defined as service robots (IFR, 2020), because they take over service tasks in the daily life of people. The earliest example of a service robot was the Roomba robot that is able to vacuum floors. These robots are growing in popularity. The international federation of robotics (IFR) reported a 37% increase in sales in 2021 compared to 2020 (IFR, 2022).

2.3. Background on hospitality robotics

In recent years, robots have also been developed specifically for the field of hospitality, where they are able to take over tasks such as preparing food and drinks, communicating with guests, or transporting items. However, the range of tasks that are being taken over by these robots is still 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.

Transportation robots transport items in hotels and restaurants. The COVID 19 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). The robots from these studies are presented as something that can be used inside a robot restaurant, for entertainment purposes. However, nowadays these robots are implemented in regular restaurants alongside human employees. 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 is derived from Automated Guided Vehicles (AGVs), which are normally used in factories to transport items (Ganesharajah et al., 1998). Shimmura et al. (2020) also refer to a restaurant robot as an AGV. Examples of transportation robots are the Pudubot (Cardona et al., 2020) and the Bellabot (Sotnik and Lyashenko, 2022). 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 SaviOne (Ackerman, 2014) and Flashbot (Pudu, 2020). 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. AGVs are also used for transporting luggage. An example of this is the TUG robot by the Aethon company, which originally designed for hospitals to transport objects (Anna, 2018; Qureshi and Syed, 2014). 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 different transportation robots are adjusted to fit the task they are used for, their sizes vary. Their basic layout, however, is extremely similar.

Reception Robots are robots that take over typical reception tasks. These robots contain a user interface that interacts with guests. This interface can consist of a tablet for visual interaction or a speech recognition and production system for auditory interaction. This interface is mounted on some sort of automated guided vehicle in order for the robot to be able to move in the environment that it works in. Examples of these robots are the Pepper (Pandey and Gelin, 2018), Temi (Hung et al., 2021), Sanbot (Luccio and Gaspari, 2020) and Cruzr robot (Aymerich-Franch and Ferrer, 2020). The robots differ in physical complexity. For example, the Temi robot only contains a tablet interface, while the Pepper robot is designed anthropomorphically and has an actual face and arms to support its communication. The only physical task that reception 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), taking input from guests and providing them with information based on the input. These robots are also able to communicate with software systems and are therefore able to set up (video) calls, check people in, handle payment, or look up information on the internet. The efficacy of these robots depends on the current development of chatbots and AI applications that are able to understand and process natural language from guests. As with transportation robots, there is a variety of different designs and models of these types of robots. However, the writers have not been able to find studies evaluating the benefits of implementing reception robots in hospitality settings.

Food Preparation Robots take over tasks in the preparation of meals in restaurants. Three examples are the Pazzi restaurant that prepares, cooks and sells pizzas without human cooks (Ware, 2021), the automatic stir fry machines from the Spyce Kitchen restaurant (Albrecht, 2020) and the Burger production robot by the company Creator (Troitino, 2018). These applications all focus on transforming raw ingredients into finished meals. Designs of food preparation robots can be found as early as 2007 (Yan et al., 2007). The structures of the different examples vary greatly. This is because the preparation of a meal consists of different tasks and therefore the robotic solutions differ per meal. 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 put 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 completely finished meal, 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). Food preparation robots all operate in restaurants with some sort of fast food business model. Traditional restaurants and hotels have not implemented these robot applications, probably because this fast food model contradicts the classical way a restaurant operates. Food preparation robots take up large amounts of space and can only cook one type of dish. The Pazzi kitchen and Spyce restaurant, for example, can use a wide array of ingredients, but can only prepare pizzas or stir fry meals respectively. Food preparation robots also do not work in close interaction with human employees. The mentioned examples serve more as production facilities 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).

2.4. Research on Hospitality Robotics

The amount of tasks that are robotised in hotels is still small. However, a number of recent publications state that robots are currently changing the hospitality industry (Belanche et al., 2021; de Kervenoael et al., 2020; Ivanov and Webster, 2018, 2019; Merkle, 2019; Nonaka et al., 2020; Pitardi et al., 2022; Pizam et al., 2022; Shin and Jeong, 2020; Tuomi et al., 2021; Vatan and Dogan, 2021). This shows how heavily the subject of hospitality robotics is being researched. The big novel aspect of hospitality robotics is the guest-robot

interaction. Traditionally, robots only needed to interact with workers of the organisations that implemented them. Interactions could be awkward at the beginning. However, employees can be trained to operate a robot properly, and when the interaction is difficult or causes problems, employees can report feedback to their managers, hoping that the issues will be solved via updated robotic interfaces. Guests, however, do not generally get prepared before interacting with a robot. They also are not required to submit feedback after an interaction. When guests have encountered a bad interaction with a robot they can simply choose not to return to the hospitality venue. Because of this, the interaction between the robot and guest needs to be carefully designed to not decrease the guest's satisfaction. 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. With reception robots especially, there is almost always a robot-guest interaction. For the food delivery robots, it is optional for the organisation that implements them to have the robots interact with guests. 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 the items off of it to complete the serving process. Up to some extent, it is up to the owner of the hospitality venue to decide how the guest robot interaction is designed.

The current body of literature on hospitality robotics can be roughly divided into two categories corresponding to the two traditional research fields of robotics and hospitality. The robotics side is concerned with designs and development of new robots as well as evaluating these in terms of efficiency and task execution. The hospitality field is concerned with how implemented robotics influence hospitality.

2.4.1. Robotics Research on Hospitality Robotics

Hospitality robotics studies from the field of robotics mostly present novel designs of a robot or robot software. Because there is a large variety of tasks in hotels, there is also a large variety in the designs of novel hospitality robotics. Designs consider robots that provide guests with information in a reception setting (Pinillos et al., 2016, Ahn et al., 2019), robots specialised in cooking (Sugiura et al., 2011; Yan et al., 2007), robots recognising 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; Hung et al., 2021; Jyh-Hwa and Kuo, 2008). 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, should they actually be implemented. 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 a representative hotel setting with actual employees and guests.

In determining the success of these robots, the focus lies on organisational benefits, referring 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 manufacturing applications, these 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 contain little to no evaluation of these factors of the robot.

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). Some of the few examples that have done this are Pinillos et al. (2016) 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 reception 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). Pinillos et al. (2016) furthermore underlines 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, requiring an update. 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. Through 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 more realistic image of the efficacy of hospitality robots can be made.

2.4.2. Hospitality Research on Hospitality Robotics

Studies from the field of hospitality 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. A number of studies solely focus on the attitudes on robots of guests (Choi et al., 2020; Piçarra et al., 2016) or employees (Ivanov et al., 2020; Pizam et al., 2022; Vatan and Dogan, 2021). 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 (Piçarra et al., 2016; Pizam et al., 2022). A number of studies compare robots with humans executing tasks in hotels and finding differences in guests' perceptions of this (Choi et al., 2020; Hoang and Tran, 2022; Kim et al., 2021; Shin and Jeong, 2020). However, these studies work with hypothetical scenarios where participants are only provided with images or video clips of the human employee and the robot and they are asked to imagine having the actual interaction themselves. These studies conclude with statements on whether guests prefer robots or humans for the execution of 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) presents 28 research questions stemming from the available literature that are still unanswered in this field. The study states that many of these questions can be answered by studying 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 (Nonaka et al., 2020; Odekerken-Schröder et al., 2022; Shimmura et al., 2020). 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. (2022) focuses 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.

What also needs to be considered is the gimmick or novelty effect that robots can have. According to Pham and Huang (2015), guests expect some kind of novelty or innovation in their experience, something that robots can offer. Kim et al. (2021) also shows that novelty is related to guest satisfaction. That is also why the Spyce restaurant, the Creator burger robot and the Pazzi pizza robot display their robots for their guests to see. The long term effects that robots have on operations therefore only become clear after this novelty effect has worn off.

2.5 Insights on the Background of Hospitality Robotics

Traditionally, there is a dichotomy between the robotics field and the hospitality field in scientific literature. Our main finding from studying the literature is that robotics researchers lack knowledge on guest experience and operational challenges in hotels and restaurants where hospitality researchers lack technical knowledge on robot design and implementation. As a result of this, most of the studies that were mentioned in this section have not studied robots in actual hotel environments.

As robots take over specific tasks, 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 seem to confirm 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.

Many guests find robots engaging because of their novelty. Novelty, however, will wear off and therefore, robots that only serve this purpose cannot help to solve personnel shortages in the long term. Tuomi et al. (2021) refers to organisations using robotics for their novelty as 'differentiating'. He also states that this is only one of the 5 ways in which hospitality organisations can use robots. The 5 ways presented are:

1. Substitute
2. Support
3. Differentiate
4. Improve
5. Upskill

This list shows different ways of looking at robotics. They can be seen as novel attractions (Differentiate), as replacements for human workers (Substitute), or as ways to assist employees, and make their jobs more enjoyable and engaging (Support, Improve and Upskill). And it is this last category, that looks most promising. In automating tasks, it is important to understand which tasks are valued by the employees. Welfare et al. (2019) studied a factory environment, where managers found the easiest task to automate was that of transportation of materials to and from assemblers. However, these transportation tasks where valued very highly by the employees because they provided social contact and exercise. Ideally, in choosing which tasks to automate, hospitality professionals take this challenge together with their employees to find out which tasks would not only reduce the amount of employees necessary, but would also improve the jobs that remain.

The few studies that did study robots in a hospitality environment from a robotics perspective (Ahn et al., 2019; Pinillos et al., 2016) provide the insights that correct implementation of novel hospitality robotics takes time and some iteration, because of problems that were unforeseen by the designers of the robot. The few real world examples from the field of hospitality by Shimmura et al. (2020), Nonaka et al. (2020) and Odekerken-Schröder et al. (2022) show that implementation of restaurant robots can have a positive effect on sales, employee satisfaction and guest satisfaction. As of now, a combination of these two things, where novel robotics are tested in a work environment and its effect on the employee, the guest and the organisation has not been studied.

3. Interaction diagrams

To analyse the possible impact that robots have on operations and on the different stakeholders in a hospitality organisation, interaction diagrams can be used. These diagrams are a way to provide insight on the full effect that robotics can have on a hospitality organisation and how the different scientific fields related to hospitality robotics are connected.

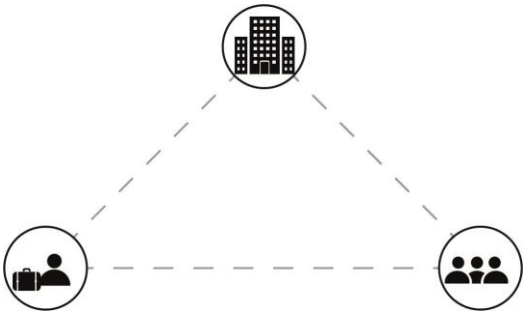

Figure 1. *Conceptual framework of the main stakeholders in a traditional hospitality work environment, namely the guests, the employees and the organisation.*
The organisation employs the employees to execute hotel tasks. The employees interact with the guests visiting the hospitality venue, and the guests interact with the organisation by paying for the received services.

Figure 1 shows a simplified interaction diagram of a hospitality work environment without robots. The three main stakeholders are the organisation (top), the guests (left) and the employees (right). The organisation employs the employees to execute tasks that keep the hotel/ restaurant running. The employees execute the tasks and in doing this, they interact with the guests. Either directly with tasks such as serving food or checking in, or indirectly by providing services such as making a comfortable bed or preparing a tasty meal. The guests then patronise the organisation by paying for the received services. A more enjoyable guest experience can result in the guest returning to the same venue and spending more, which keeps the organisation running. There are also indirect interactions possible. For example, when an organisation suddenly decides to pay its employees less, the employees might get frustrated. Employees that are unsatisfied or stressed are less motivated to provide service to guests and engage in executing hotel tasks (Laškarin Ažić, 2017). This could then result in less happy guests because the employees are less dedicated towards the guests, which in turn affects the organisation negatively.

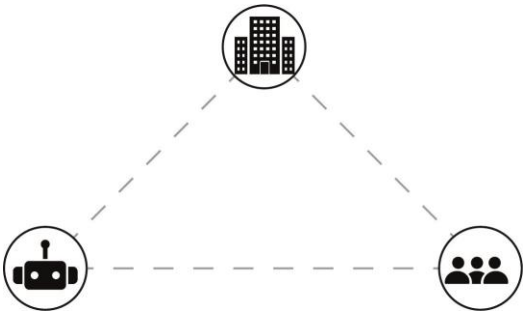

Figure 2. *Conceptual framework of the main stakeholders in a traditional work environment with robots, namely the robots, the employees and the organisation.*
The organisation employs the employees to execute production tasks. The organisation also 'employs' robots to execute certain production tasks and the robots benefit the organisation by making the production process more efficient/ less costly. The employees interact with the robots by operating them and on points where their tasks meet.

Figure 2 shows a similar simplified interaction diagram of an industrial work environment with robots. Here, the three main stakeholders are the organisation (top), the robot(s) (left) and the pool of employees (right). The dashed lines represent interactions between these stakeholders. The interaction between the robot and the organisation is an abstract one. It entails an organisation implementing a robot and the robot, when implemented, having an influence on production and efficiency, therefore having an influence on the organisation's turnover. The interaction between the employees and the robot is a more direct one. Since robots take over certain physical tasks that used to be human tasks, the employees now need to operate and monitor the robot. In robotics research, these two interactions are most important. If a robot does not benefit an organisation, there is no reason for it to get installed, so the robot needs to have clear benefits for a company that would implement it. The robot also needs to be operated by workers, so designing this interaction well is crucial for the successful operation of a robot. The interaction between the employees and the organisation represents the employees executing tasks for the organisation and the organisation paying the employees in return. Stakeholders can also interact indirectly. The interaction between employees and organisation, for example, can also be influenced by the robot when it enters the work environment. This happens as the robot takes over tasks, thereby changing the job that remains for the human employees. The job of the employees might improve, making them happier, or it could become less interesting, making workers less happy. Happiness of employees is related to how well they function and how often they become ill, which affects the organisation. The result of implementing a robot 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 add to more interesting and rewarding jobs for the remaining employees, making them happier. Also, as an organisation implements robots, new jobs might become available such as monitoring and maintenance tasks to keep the robot operational.

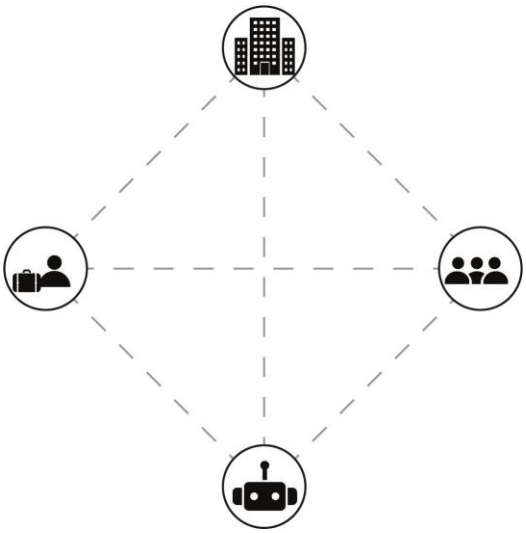

Figure 3. *A conceptual framework to indicate possible impacts of introducing a robot (bottom icon) into a hospitality environment, consisting of the organisation (top), the guest(s) (left), and the employee(s).*
The dashed line might be replaced by an arrow from one element to the other, denoting a 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).

To make an interaction diagram that illustrates a hospitality organisation with robots in them, the two aforementioned diagrams are combined, resulting in the diagram from Figure 3. There are no new stakeholders

and there is only one new line, which is the one between the robot and the guest. However, this does not mean that the only new thing about hospitality robotics is this interaction between guests and robots. The interaction diagram gives insight on how the different stakeholders are now connected via each other. Just like robots can benefit organisations via its employees, interactions can influence every stakeholder indirectly.

3.1. Needs and expectations of different stakeholders

In a hospitality setting, stakeholders have certain expectations and needs. Understanding these can help in determining whether an interaction has a positive or a negative effect.

Guests expect to be treated hospitable. This means the employees execute tasks such as cooking, cleaning, preparing a room, to give the guest the best possible experience. Hedonic happiness refers to pleasure and enjoyment to get a happier life (Delle Fave et al., 2011, 8) and is something that guests expect to find in a hotel, in the form of, quality food and drinks and a comfortable bed, and in hospitable services delivered in an authentic way (Seyitoğlu and Ivanov, 2022).

Employees expect a salary in exchange for the tasks that they execute in a hotel. Employees, however, should not merely be regarded as people that execute tasks for a salary. Employees experience stress and exhaustion 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 need to do their work. The JD-R model states that certain tasks 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, increase job resources. This is also underlined specifically for hospitality organisations by Yang (2010), which states that as hotel employees have more social contact, autonomy and engagement, their job satisfaction is increased and employee turnover is reduced. This type of satisfaction that employees expect is referred to as eudaimonic happiness (Delle Fave et al., 2011), which is also called long term happiness and refers to people feeling fulfilled and needed in life. This eudaimonic happiness differs from hedonic happiness that guests expect.

The primary need of the *Hospitality Organisation* is to keep operations running. For this to happen, it needs money paid to it by the guests visiting the hotel or restaurant. It is thus in the interest of the organisation to ensure that the guests are satisfied. For the organisations, it is also necessary that the employees stay happy (Chi and Gursoy, 2009). Decreased affinity with the hospitality organisation increases turnover intention, which increases costs for the organisation and reduces service quality (Iverson and Deery, 1997; Laškarin Ažić, 2017).

Although *Robots* do interact with the other stakeholders, they do not have any needs or desires. In their operation, they are able to influence the other stakeholders, having an impact on their needs and desires (Shimmura et al., 2020).

3.2. A combination of scientific domains

As the diagrams have shown which stakeholders and interactions are at play in hospitality environments, various scientific fields are related to this subject a well.

Hospitality Research is currently the field that produces the highest number of publications on hospitality robotics. The studies shed light on how robots are perceived in the hospitality world and gain insights that can be used to update robotic designs.

The properties and limits of the robot are determined by its physical design. So robotics design has a large influence on the manifestation of new hospitality robots and the final work process and employee-robot and guest-robot interactions that arise. Also, insights from implementing robotics can be used to adapt robot designs to increase the successful operation of robots, as Pinillos et al. (2016) shows.

Human Robot Interaction (HRI) is also a research field closely related to hospitality robotics. Robotic design often occurs along with designing the interaction interface. However, hospitality robotics also opens the door to new and unexplored human robot interactions where interactions need to be designed in such a way that laypersons, guests in this case, can also operate the robot without prior knowledge and without it reducing their guest experience. El Hafi et al. (2020) explains that, while robotics is becoming more popular, the interactions between customers and robots in day-to-day service encounters are still challenging because of a mutual lack of understanding.

As robots impact the jobs of human employees, the fields of *Human Resources* and *Talent Management* also become connected to this. Especially since the problem that robots are meant to solve are personnel shortages and high turnover, implementing hospitality robotics should be focused not only on keeping the guests satisfied, but also on turnover intention and job satisfaction of the employees. Moniz (2014) explains that robotic engineers often don't consider how new industrial robots will impact jobs and work culture, and how this can result in jobs being impacted negatively. It is possible that future publications on hospitality robotics can come from all of these aforementioned scientific angles. However, for in depth analyses of robotics as a solution for the problems of staff shortage and turnover, these fields need to be joined, therefore making use of the knowledge from every aspect of this complex subject. Also, the evaluations of robots in practice need to be based on physical experiments in representative environments.

4. Exemplary cases

To illustrate how the aforementioned interaction diagram can be used, two specific cases of food delivery robots in restaurants from academic publications are analysed. In the first case, the robots bring about a positive impact on the various interactions. In the second case, they do not.

4.1. Food delivery robots implemented correctly

The first example concerns a Japanese restaurant implementing food delivery robots. The effect of these robots on the restaurant are discussed in Shimmura et al. (2020) and Nonaka et al. (2020). Both papers discuss the same restaurant with food delivery robots installed. The restaurant in Kyoto has 441 tables and four robots are implemented. The robots are adjusted to match the interior of the restaurant as to not draw attention towards them. The robots do not interact with guests, only with employees who take the food from the robots and serve it to the customers at the tables. After the robots were introduced, Shimmura et al. (2020) reports increased sales per hour. Nonaka et al. (2020) furthermore reports increased employee happiness, mostly due to the fact that waiters needed to make less runs to the kitchen after the robots got installed. Figure 4 shows an interaction diagram for this case.

The 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 directly. This interaction (line 2) is positive, since the employees enjoy the fact that they need to run to the kitchen less often. Line 4, between the organisation and the guests is also affected positively, as sales increased. This could have happened because employees have more time to interact with guests, which increases their hedonic happiness (line 3). As explained earlier, employees that have more time for the aspects of their jobs that they enjoy, have increased eudaimonic happiness, which in general causes less strain and turnover (Yan et al., 2007), which in turn benefits the organisation employing them (line 5).

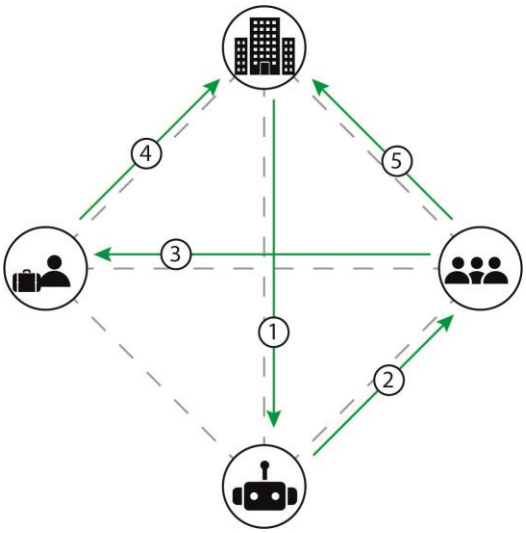

Figure 4. *Interaction lines influenced by a restaurant robot.*
(1) The organisation implements the robot to transport items from the kitchen to the restaurant floor. (2) The employees need to head to the kitchen less often for items, increasing their eudaimonic value. (3) The employees have more time 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 reduces employee turnover.

4.2. Food delivery robots implemented poorly

The second case study is taken from one of the restaurants discussed in Seyitoğlu and Ivanov (2022). This study evaluates 582 online reviews of restaurants that have robots implemented. Most reviews are positive of robots in restaurants, and many reviewers went to a robot restaurant just to experience robots. However, in some of the restaurants, robots deliver items to the wrong table from time to time. When this happens, employees need to step in to fix the problems. Reviews about these situations show that guests don't enjoy this. An interaction diagram for this situation is shown in Figure 5. Line 1 is positive, since the organisation implements the robot. Line 2 is negative, since the guests are unhappy with the robot making errors. Line 3, between the robots and employees is also negative, because human employees need to step in and fix the problems and they experience less eudaimonic happiness. 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, as shown in the previous case, could cause reduced sales (line 5). Finally, line 6 is also negative, as less happy employees affect the organisation negatively.

These are just two examples in which robots implemented in restaurants influence every stakeholder, directly or indirectly, positively as well as negatively. The interaction diagram illustrates how all stakeholders are connected in a work environment. It can therefore be used as a tool to predict the full effect that a robot might have on a hospitality work environment before it is implemented. For each different task, the diagram might look different and for some tasks, this diagram can be too limited. There might be more stakeholders or more complex interactions. For example, as was mentioned earlier, there is the case where a robot relieves employees of repetitive work to such an extent that the amount of work reduces and one employee is let go. In this example, the fired employee is affected negatively, while the remaining employees may experience increased job satisfaction in the remaining tasks. For analysing such cases, more detailed interaction diagrams might be necessary.

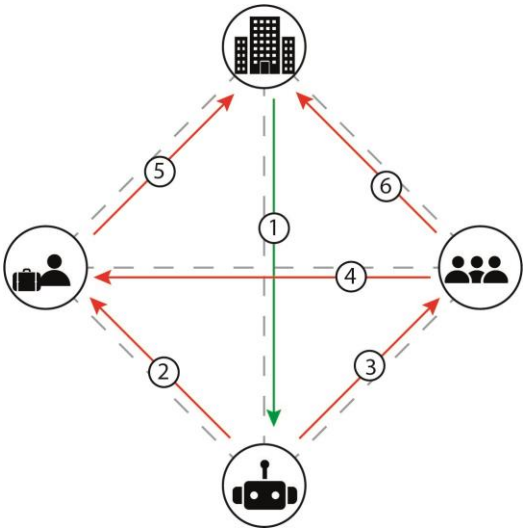

Figure 5. *Interaction lines influenced by a restaurant robot.*
(1) The organisation implements the robot to transport items from the kitchen to the restaurant floor. (2) The robot delivers wrong items to guests, reducing their satisfaction and hedonistic happiness. (3) Employees need to step in to fix 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.

5. Discussion and Conclusion

Traditionally, hospitality research is largely concerned with guest satisfaction. However, the issues that hospitality faces today are centred around the employees, mainly the personnel shortages and high turnover. These are also the issues that hospitality robotics might be able to solve. While deploying these robotic solutions, guest experience should not be reduced and the organisation implementing the robot should also not suffer. The subject of hospitality robotics therefore ties these four stakeholders together. There currently is a split in academic research showing that this subject is mostly studied from a hospitality angle or a robotics angle, often focusing on only one of the stakeholders. The interaction diagram presented in this article serves as a starting point for predicting and evaluating the full effect that a robot will have on a hospitality work environment.

If the problem of personnel shortages will remain urgent, it is likely that robotics research in the future will also focus on automating tasks that currently don't have a robotic alternative. Designing these new robots in a way that does not affect the various stakeholders negatively requires a level of understanding of the different interactions in play. One of the simplest examples, the food delivery robot from Nonaka et al. (2020) and Shimmura et al. (2020), demonstrates the potential of hospitality robotics, but also its current limitations. In the ideal future scenario, hospitality robotics is studied from a multidisciplinary view, taking into account all stakeholders, thereby contributing to reducing personnel shortages and improving job quality.

6. Limitations and Future Research

The interaction diagram is conceptual. The cases that were analysed are both examples of transportation robots. When different tasks are automated, the interactions can be different or more complex than the ones described. Different robotics might also require an alternative view on stakeholders. Shin (2022), for example, states that society can also be seen as a stakeholder in hospitality processes.

For the case of food delivery robots, research points out how every stakeholder can benefit from hospitality robotics, but also how easy it is to let the implementation go awry. Future research directions could focus on empirical studies on the specific points of implementation and how they affect the success of a robot for different tasks. Also, high level robotic research on specific challenges of robotising certain tasks in hotels could help selecting the next task to automate. Ideally, when studying these processes, the different stakeholders are taken into account, which results in human-robot interactions that will benefit employees, guests and hospitality organisations.

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