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Beyond the Dyad

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BEYOND THE DYAD

SHIFTING GEARS IN HUMAN-ROBOT INTERACTION ACROSS SERVICE INDUSTRIES

MARK MARTINUS HENDRIK MARIA GERARDUS STEINS

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Beyond the Dyad

Shifting Gears in Human-Robot Interaction Across Service Industries

DISSERTATION

to obtain the degree of Doctor at Maastricht University
on the authority of Rector Magnificus, Prof. Dr. Pamela Habibović
and to obtain the degree of Doctor of Philosophy
in accordance with the rules and regulations of Queensland University of Technology,
in accordance with the decision of the Board of Deans,
to be defended in public on Friday the 27th of June 2025, at 10.00 hours

by Mark Martinus Hendrik Maria Gerardus Steins

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LIST OF ABBREVIATIONS

AI - Artificial Intelligence
ANT - Actor-Network Theory
EDLAB - Centre for Teaching & Learning, Maastricht University
HsRsI - Humans-Robots Interactions
IAT - Intelligent Assistive Technologies
ICT - Information and Communication Technology
MCR - Maastricht Center for Robots
NASSS - Non-adoption, Abandonment, Scale-up, Spread, and Sustainability
PBL - Problem-Based Learning
PVI - Public Value Innovation
PwID - People with Intellectual Disabilities
QUT - Queensland University of Technology
UM - Maastricht University
SDG - Sustainable Development Goal
TPR - Telepresence Robot
WHO - World Health Organization

CHAPTER 1

INTRODUCTION

1.1. PEDAL INTO TOMORROW

1.1.1. Service robots are riding alongside us

Service robots are becoming increasingly popular in service delivery across industries, from restaurants and hotels to healthcare and education (Phillips *et al.*, 2025, Steins *et al.*, 2024; Merx *et al.*, 2025; Mennens *et al.*, 2024). These "system-based autonomous and adaptable interfaces" interact, communicate, and deliver services to various stakeholders, including customers and employees (Wirtz *et al.*, 2018). While their growing presence transforms organizational frontlines, service robots vary significantly. Their variety in autonomy and customization possibilities influences how humans and robots interact, impacting both service delivery and value creation. For instance, in hospitality settings, some service robots autonomously serve customers while following predefined routines, offering limited customization options (Odekerken-Schröder *et al.*, 2022). In contrast, several healthcare applications feature robots with lower autonomy but higher customization possibilities, where healthcare professionals can extensively adapt robot behavior to meet individual client needs (Čaić *et al.*, 2018; Mahr *et al.* 2024). This variety in autonomy and customization options is reflected in the growing sophistication of human-robot interaction (HRI) at service frontlines as it often determines how end-users— customers, clients, students, and frontline employees (FLEs)—can influence and adapt robot behavior to their specific needs. In turn, this distinction underscores the dual roles of service robots, with high-autonomy robots often substituting human labor in routine tasks and low-autonomy robots augmenting human capabilities through adaptable and collaborative interactions in human-robot teams (De Keyser & Kunz, 2022).

This dissertation investigates how physically embodied service robots (Jörling *et al.*, 2019), varying in their levels of autonomy and customization by end-users, contribute to value creation across diverse service settings. Drawing upon Actor-Network Theory (ANT; Law & Hassard, 1999)—which posits that constellations of humans and non-human entities interact within a network, co-creating meaning and shaping each other's actions—this research moves beyond simple dyadic relationships between a single user and a robot. As referenced in the title, this dissertation moves *"beyond the dyad"*, and investigates service robots within increasingly complex constellations of actors. Specifically, this dissertation aims to answer the following overarching research question:

How do the roles and characteristics of service robots affect various constellations and relationships (human and non-human) in real-world service settings?

Beginning with the *service triad* in a *hospitality* setting, focusing on customer-robot interactions while considering FLEs (Chapter 2; Odekerken *et al.*, 2022), this dissertation progresses to examine collective service experiences in *hospitality* where *customers in groups* jointly make sense of robot encounters (Chapter 3; Steins *et al.*, 2024). It then explores robot-mediated *team interactions* in *hybrid classrooms*, where both face-to-face and remote users collaborate in *higher education* (Chapter 4). The investigation further extends to *triadic interactions* in *healthcare* involving robots, clients, and frontline employees (FLEs), highlighting how FLEs and clients with intellectual disabilities collaboratively implement and customize robots to generate value for both actors. (Chapter 5). While these chapters focus on different service settings taking a micro-level perspective, the dissertation ultimately transcends to a macro-level by adopting a broader ecosystem perspective. It examines how organizational and inter-organizational activities and strategies in *Service Robot-based innovation* enable service robots to create value for end-users in *healthcare* settings (Chapter 6; Mahr *et al.*, 2024).

1.1.2. Accelerating the momentum of service robots

Service robots' increasing adoption across industries is driven by both technological advancements pushing innovation forward and pressing service challenges pulling for solutions. The push factors primarily stem from significant improvements in robot capabilities. Advances in artificial intelligence and adaptable interfaces enable robots to operate more autonomously in unstructured environments, while improvements in physical embodiment and user interfaces, along with increased customization options, make human-robot interaction more natural and intuitive (Wirtz *et al.*, 2018; De Keyser & Kunz, 2022; van Doorn *et al.*, 2017).

At the same time, global challenges in service sectors drive a strong demand for innovative solutions, including the potential use of service robots. According to the World Health Organization, a *global shortage* of 10 million healthcare workers is projected by 2030, driven by a *shrinking workforce* and *rising demand* for healthcare services due to aging populations. To address these challenges, further uptake of assistive technologies is a potential solution, offering new ways to keep healthcare services available and accessible (WHO, 2024). Similarly, hospitality and retail sectors face significant *staffing challenges*, particularly for repetitive or physically demanding tasks (Wirtz & Zeithaml, 2018; Huang & Rust, 2018, 2021). These workforce challenges drive organizations to explore how service robots can substitute or augment human employees to maintain service quality and efficiency (De Keyser *et al.*, 2019).

The convergence of improved technological capabilities and pressing workforce needs has accelerated service robot adoption. Globally, the deployment of service robots experienced a strong annual growth rate of 13% between 2020 and 2022, with particularly notable increases in the hospitality sector (an 85% rise in robot sales in

2021) and healthcare, where robot usage for rehabilitation, therapy, and assisted living grew by 23% (International Robotics Federation, 2023; Lu *et al.*, 2020). Driven by the increasing applications of service robots across diverse service settings, more recent projections indicate that the service robotics market is expected to grow from USD 41.10 billion in 2024 to USD 98.65 billion by 2029, with a compound annual growth rate (CAGR) of 15.9% (MarketsandMarkets, 2024).

1.1.3. Chasing the service robot revolution

It has been hailed as a service revolution—a promise to transform the way services are delivered by enhancing operational efficiency and elevating customer experiences (Lu *et al.*, 2020). Service robots are being implemented across a growing number of organizations, spanning industries such as healthcare, hospitality, retail, and education. From assisting clients in long-term care facilities to serving customers in restaurants and retail environments, and even supporting students with robotic teaching assistants, the potential applications appear limitless (Čaić *et al.*, 2018; Phillips *et al.*, 2023; De Keyser & Kunz, 2022; Mennens *et al.*, 2024). For instance, at a Western European university, students engage in conversations with "*Robot Teacher Robin*" and use the robot to assist them with their assignments (Mennens *et al.*, 2024).

However, despite this anticipation of a robotic revolution and the potential benefits of service robots, many robot-deployments struggle to deliver on their potential (e.g., Belanche *et al.*, 2020b, Pitardi *et al.*, 2024). This gap between promise and reality underscores the challenges of integrating robots into real-world service settings. Service robots have often failed to meet expectations or been discontinued after initial deployment. For instance, numerous retail organizations have withdrawn their robotic assistants due to concerns about their effectiveness in enhancing customer experiences. Similarly, in healthcare settings, some therapeutic robots have been abandoned due to integration difficulties with existing care practices (Blindheim *et al.*, 2022; Hung *et al.*, 2023). These failures often stem from a mismatch between technological capabilities and user needs, insufficient integration with existing service processes, or inadequate understanding of how robots collaborate with frontline employees and affect service interactions (Le *et al.*, 2024; Lu *et al.*, 2020; Phillips *et al.*, 2023).

Current research offers limited guidance for addressing these challenges. Most studies have primarily focused on organizational benefits such as cost reduction and operational efficiency (e.g., Wirtz & Zeithaml, 2018), while the impact on end-users - both customers (or patients in healthcare, residents/clients in long-term care and students in education) and employees who interact with these robots daily - remains understudied. While real-world deployments of service robots are advancing rapidly, much of the existing research remains confined to controlled laboratory environments (e.g., Choi *et al.*, 2019; Ho *et al.*, 2020), overlooking the messy realities and complexities of integrating robots for different constellations of actors in service settings. Moreover, existing knowledge is often conceptual (e.g., Belanche *et al.*, 2020a; Huang & Rust, 2018; van Doorn *et al.*, 2017). While some scholars have conducted valuable field studies examining real-world robot implementations (e.g., Odekerken *et al.*, 2022; Schepers *et al.*, 2022; Yam *et al.*, 2021), present research on service robots misses out on the social complexity that determines technology adoption in real-world service settings (De Keyser & Kunz, 2022; Lu *et al.*, 2020). This social complexity arises from the interactions and relationships within constellations of human actors and robots, where collective experiences (Chapter 3) and group dynamics (Chapter 4) play a critical role in shaping how the technology is perceived and used. This social context is not only inherently tied to real-world contexts but also derives their meaning from them, making them difficult, if not impossible, to fully replicate in controlled laboratory environments. For instance, in hospitality settings, customers often experience service robots as part of a group, collectively dealing with and making sense of their robot encounters - a dynamic that influences their shared understanding of the technology and subsequent behaviors (Chapter 3).

The dissertation aims to *chase the realities of service robots* beyond the lab and *into the field*, where their promises and limitations are truly tested. It does so by examining *real-world implementations* across *diverse service setting*s, focusing on how *various constellations of actors* interact with, adapt to, use and customize service robots in their daily environments.

1.2. RIDE THE ROADS LESS TRAVELLED - A JOURNEY IN SERVICE ROBOT RESEARCH

1.2.1. Off the Trainer and Into the Race: Real-World Studies of Service Robots in Action

Early service robot research set important foundations by examining the dyad of one type of user (e.g., customer or employee) interacting with a service robot, establishing crucial insights about fundamental interaction patterns and user acceptance (Wirtz *et al.*, 2018). However, real-world service contexts involve multiple stakeholders, including other customers and frontline employees, as service is increasingly provided by constellations of humans and robots (De Keyser & Kunz, 2022). The presence of these other individuals fundamentally alters the dynamics of HRI, as third-party roles and the relationships between human actors influence how interactions with robots unfold. These more complex social environments and constellations of actors need to be studied to understand how HRI influences and is influenced by the broader network of actors. (Odekerken-Schröder *et al.*, 2022; Phillips *et al.*, 2023; Steins *et al.*, 2024).

This dissertation moves beyond controlled environments - *the training grounds* - to study robots in real-world service settings - *the actual race.* By doing so, it aims to capture the social complexity that surrounds HRI in authentic service environments. The rich context of real-world implementations reveals how different constellations of actors—customers, students, clients, employees, and robots—interact and adapt to each other's presence and actions, while the relationships within the network are shaped by the robot's presence, role and influence. Echoing Castelo *et al.*'s (2023, p.2) sentiment that "the use of new technologies does not occur in a vacuum," while laboratory studies provide valuable initial insights, they cannot fully capture these dynamic social interactions where multiple actors influence and shape technology adoption and use (Mende *et al.*, 2019; Lu *et al.*, 2020; Odekerken-Schröder *et al.*, 2022).

1.2.1. The Breakaway: Closing the Distance in Service Robot Research

A breakaway in cycling occurs when a rider or small group accelerates ahead of the main peloton to establish a leading position in the race. Similarly, this dissertation aims to advance current knowledge in service robot research by breaking away from existing approaches in three significant ways. First, while service robots are increasingly deployed across industries, most existing research is either conceptual or based on controlled laboratory studies (De Keyser & Kunz, 2022; Lu *et al.*, 2020; Mende *et al.*, 2019), failing to capture authentic behavior in actual service environments. This dissertation moves beyond controlled settings to examine HRI in real-world service settings.

Second, beyond the nature of studies, foundational service robot research typically examines dyadic interactions between one type of user and a robot, despite real service settings involving multiple actors interacting simultaneously or being co-present (Abboud *et al.*, 2021; De Keyser *et al.*, 2019). By investigating service robots in progressively complex constellations of actors - from triadic service encounters in hospitality (Chapter 2 - Odekerken-Schröder *et al.*, 2022) to collective experiences in hospitality (Chapter 3 - Steins *et al.*, 2024) to team interactions in higher education (Chapter 4), and implementation cases of robot, client and healthcare professionals in long-term care (Chapter 5) - this research aims to capture some of the social complexity that surrounds HRI in real-world settings and provides novel insights into how service robot transform relationships between human actors in different service settings.

Third, despite growing adoption, many service robot implementations fail due to misalignment between technological capabilities and user needs, or insufficient integration with existing service processes (Blindheim *et al.*, 2022; Hung *et al.*, 2023). This dissertation addresses these challenges by examining barriers and facilitators of sustained robot use (Chapter 5) and Service Robot-based Innovation in innovation ecosystems (Chapter 6 - Mahr *et al.*, 2024).

1.3.1. Actor Network Theory: The connecting chain in this dissertation

Just as the chain in a bicycle provides the essential connection between its components, Actor-Network Theory (ANT; Law & Hassard, 1999) serves as the critical link in understanding the relationships between human and non-human actors across the various constellations, as included in the chapters of this dissertation. The theory allows for reflection on the roles played by human and non-human actors and the relationships between those actors within service networks (Čaić *et al.*, 2018). This theoretical lens reveals how both human and non-human actors (e.g., service robots) exercise agency through their capacity to affect and be affected by other entities in the network (Sayes, 2014). Particularly important is understanding how service robots, as non-human actors, potentially transform existing relationships between human actors, what Phillips *et al.* (2023) refer to as the intrusion challenge.

Specifically in this thesis, ANT provides a lens to understand how service robots and the roles they perform influence existing service relationships in various constellations of end-users and service settings - from customer-employee interactions in hospitality (Chapter 2 - Odekerken *et al.*, 2022), to groups of customers during collective service experiences in hospitality (Chapter 3 - Steins *et al.*, 2024), to on-site and remote students in collaborative learning environments in higher education (Chapter 4), and to the intricate relationships between caregivers and clients in healthcare settings (Chapter 5). ANT is especially valuable because it recognizes that service robots actively shape interactions rather than simply carrying out pre-programmed tasks without any impact on the relationships around them (Sayes, 2014). This theoretical foundation helps explain how service robots become meaningful actors in the aforementioned service settings and acknowledges that their role extends beyond individual interactions to broader service systems (Chapter 6 - Mahr *et al.*, 2024). In sum, ANT offers this dissertation three foundational elements, (i) the constellation of actors involved, (ii) their specific roles within the network, and (iii) the relationships between these actors that describe the variations across the chapters.

1.3. EXPLORE THE THESIS - A GUIDED TOUR

This dissertation aims to enrich our understanding of the impact of different types of service robots, each performing distinct roles, on relationships between actors within various constellations, across diverse real-world service settings. While existing research has primarily focused on dyadic interactions between one type of user (e.g., one customer or one employee) and a robot, this dissertation examines service robots in increasingly complex constellations of actors. To systematically investigate these varying constellations, the dissertation encompasses studies across three key service sectors - hospitality, education, and healthcare. This multi-sector approach enables examination of how different types of service robots transform relationships between human actors across diverse service contexts, from more standardized, transactional settings like restaurants to highly personalized care environments.

As outlined in **Table 1.1**, each chapter investigates a unique research question exploring specific aspects of human-robot interaction within these service settings. The progression of research questions reflects increasing complexity in both the constellations of actors studied and the roles service robots perform - from examining service triads in hospitality (Chapter 2) to analyzing ecosystem-wide innovation in healthcare (Chapter 6). This evolution required studying six different service robots, each with varying levels of autonomy and customization capabilities, to understand how these characteristics influence relationships between human actors in different service contexts.

The methodological approach is predominantly based on mixed methods designs, combining quantitative and qualitative techniques to capture both the breadth and depth of HRI in real-world settings. This methodological choice reflects the complexity of studying service robots "in the wild" where controlled experiments alone cannot fully capture the social dynamics at play. By combining field studies with lab experiments, this dissertation aims to produce relevant research that maintains methodological rigor while capturing real-world complexity (van Doorn *et al.*, 2025).

Table 1.1. Overview of chapters

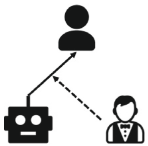
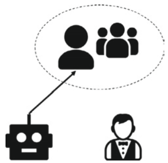
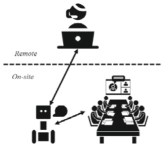
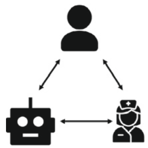
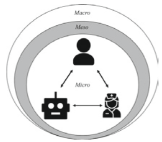
	Chapter 2: Hospitality triad	**Chapter 3**: Hospitality groups	**Chapter 4**: Education teams	**Chapter 5**: Healthcare triad	**Chapter 6**: Healthcare ecosystem
Actor focus	Triad, focus on customer, considering the role of FLE	Groups of customers during collective service experiences	Teams of on-site and remote users (students)	Triad, client & FLE (healthcare professional)	Micro, meso and macro-level actors/ stakeholders in Service Robot-based innovation ecosystems
					
Research question	How does service robots' perceived value influence repatronage intention and how does frontline employee interaction quality affect this relationship?	How do customers deal with HRI during collective service experiences, and how do these processes influence shared reality formation and post-purchase outcomes?	How does a telepresence robot influence group conditions and student engagement in hybrid small-scale collaborative classrooms?	What value does sustained use of social robot Ivy create for clients & healthcare professionals?	How to develop and manage Service Robot-based Innovation ecosystems that create Public Value?

Table 1.1. Continued

	Chapter 2: Hospitality triad	**Chapter 3**: Hospitality groups	**Chapter 4**: Education teams	**Chapter 5**: Healthcare triad	**Chapter 6**: Healthcare ecosystem
Robot - *Autonomy* - *Customization options* - *Role*	Amy & Akatar *Autonomy: Medium* Perform semi-autonomous tasks, navigate environments but require pre-programmed instructions. *Customization: Low* Pre-programmed functionalities with no options for customization by end-users. *Robot role*: *Servant*	Relay and LuckiBot *Autonomy:* Medium Perform semi-autonomous tasks, navigate environments but require pre-programmed instructions. *Customization: Low* Pre-programmed functionalities with no options for customization by end-users. *Robot role: Focal point*	TEMI *Autonomy: Low* The telepresence robot is controlled by a remote user. *Customization: Medium* Remote users can navigate freely and adjust viewing angles. *Robot role: Facilitator*	Ivy *Autonomy: Medium* No independent decision-making but executes pre-programmed tasks. *Customization: High* Users can extensively customize and adapt robot behavior to meet specific needs. *Robot role: Assistant*	Ivy *Autonomy: Medium* No independent decision-making but executes pre-programmed tasks. *Customization: High* Users can extensively customize and adapt robot behavior to meet specific needs. *Robot role: Enabler*
Service setting	Restaurant	Hotel & Restaurant	Higher Education	Long-term Care	Long-term Care
Principal theoretical lens	Social presence (Biocca *et al.*, 2003) Value creation (Deci & Ryan, 1985)	Appraisal theory (Lazarus & Folkman, 1984) Shared reality (Rossignac-Milon & Higgins, 2018)	Team learning (van den Bossche *et al.*, 2006)	NASSS framework (Greenhalgh *et al.*, 2017) Adaptive implementation model (Meiland *et al.*, 2004)	Public Value Innovation (PVI; Spanjol *et al.*, 2024) Innovation ecosystem theory (Adner, 2017)

Table 1.1. Continued

	Chapter 2: Hospitality triad	**Chapter 3**: Hospitality groups	**Chapter 4**: Education teams	**Chapter 5**: Healthcare triad	**Chapter 6**: Healthcare ecosystem
Nature/ Manuscript type	Empirical: Mixed methods	Empirical: Mixed methods	Empirical: Mixed methods	Empirical: Qualitative	Conceptual with illustrative case
Data	- Exploratory field observations: n = 9 hours - Study 1: n = 108 restaurant customers - Study 2: n = 361 MTurkers	- Study 1: n = 1107 online hotel reviews - Study 2: n = 310 restaurant customers	- Study 1: n = 156 students across 17 tutorial groups responding to a longitudinal survey in T1 and T2. - Study 2: n = 10 interviews	19 cases across 6 care organizations (interviews with healthcare professionals) n = 19 interviews,	Illustrative case

Table 1.1. Continued

	Chapter 2: Hospitality triad	**Chapter 3**: Hospitality groups	**Chapter 4**: Education teams	**Chapter 5**: Healthcare triad	**Chapter 6**: Healthcare ecosystem
Manuscript submission status	Published in the *Journal of Service Management*	Published in the *Journal of Business Research*	Submitted to the *Internet and Higher Education*	Submitted to the *Journal of Medical Internet Research*	Published in the *Journal of Product Innovation Management*
	Odekerken-Schröder, G., Mennens, K., **Steins, M.**, & Mahr, D. (2022). The service triad: an empirical study of service robots, customers and frontline employees. *Journal of Service Management*, 33 (2), 246–292.	**Steins, M.**, Becker, M., Odekerken-Schröder, G., Mathmann, F., Mahr, D., & Russell-Bennett, R. (2024). Do we think and feel alike? Field evidence on developing a shared reality when dealing with service robots. *Journal of Business Research*, 180, 114729.	**Steins, M.**, Mennens, K., Beausaert, S., Mahr, D., Odekerken-Schröder, G., Mariş, A., Mathmann, F. The impact of a telepresence robot on group conditions and student engagement in small-scale collaborative hybrid classrooms: A mixed-method field study in higher education. *The Internet and Higher Education.*	**Steins, M.**, Huijnen, C., Odekerken-Schröder, G., Mahr, D., Mennens, K., Daniels, R., and Mathmann, F. Facilitators and Barriers to Sustained Use of Social Robot Ivy for People with Intellectual Disabilities: A Qualitative Study on Healthcare Professionals' Experiences. *Journal of Medical Internet Research.*	Mahr, D., Odekerken-Schröder, G., & **Steins, M.** (2024). Service robots and innovation: An ecosystem approach. *Journal of Product Innovation Management.*

1.3.1. Chapter 2. Service triad in hospitality

The first empirical chapter, published in the *Journal of Service Management* (Emerald Publishing - JOSM, n.d.), investigates how service robots, customers, and frontline employees (FLEs) interact in *hospitality* services, specifically examining how these three actors form a *service triad*. This chapter explores how *Amy and Akatar* (**Figure 1.1)**, both service robots with relatively low customization capabilities but medium autonomy influence customer repatronage intentions in a fast-casual restaurant setting. The robots' role is best described as *a servant*, serving as a bridge between customers and the service provider, delivering food and drinks while facilitating basic interactions between customers and the restaurant.

Through a mixed-methods approach combining field observations, a field study in the restaurant and online experiments, this chapter examines how the service robot's perceived value and frontline employee interaction quality shape customer responses. Drawing on ANT to explore the interplay between human and non-human actors, this chapter offers insights into how service robots transform existing relationships between human actors in hospitality settings (Larivière *et al.*, 2017; Phillips *et al.*, 2023), particularly how FLEs and robots can work in tandem to enhance the customer experience.

Figure 1.1. Amy (left) & Akatar (right)

While Chapter 2 focuses on a *triad of robot-customer-FLE interactions*, offering insights into the *customer's perspective* and the role of the FLE in shaping service outcomes after customer-robot interactions, the next chapter broadens the scope to collective service experiences in hospitality.

1.3.2. Chapter 3. Customer groups in hospitality

This chapter, published in the *Journal of Business Research* (Elsevier - JBR, n.d.), shifts focus to examine how groups of customers collectively experience and make sense of service robot encounters in *hospitality* settings. The research investigates how customers in groups appraise and cope with HRI during *collective service experiences*, and how these processes influence the development of a *shared reality* regarding the service robot. Acknowledging the importance of realism in service contexts, this chapter emphasizes that customers rarely interact with robots in an isolated dyad of one customer and one robot. Instead, in industries such as hospitality, customers often consume services as part of a group, interacting with both the robot and each other. This dynamic underscores the importance of exploring not only individual customer-robot interactions but also the collective interpretations and responses that emerge within groups. Drawing upon appraisal theory (Lazarus & Folkman, 1984) and shared reality theory (Rossignac-Milon & Higgins, 2018), the study investigates how customers in groups jointly make sense of their service robot encounters. In this context, *Relay* & *LuckiBot* (**Figure 1.2)** - both hospitality robots with medium autonomy and low customization options, similar to those discussed in Chapter 2, serve a different role—transforming from merely being a direct service provider to becoming an integral element of the servicescape, a *focal point* that customers bond over and collectively make sense of.

Figure 1.2. Relay (left) & Luckibot (right)

Through analysis of over 1,000 online hotel reviews and a field study with 310 restaurant customers, this chapter examines how customers' initial responses to service robots during collective service experiences shape their individual and shared coping strategies, ultimately leading to a shared reality about the service robot. As actors within the broader service network, these robots not only deliver services but also transform social dynamics among customers, serving both epistemic and relational needs through their presence within the service environment.

Moving from hospitality to education, the next chapter examines how a service robot that offers *telepresence* mediates interactions between on-site and remote students in collaborative learning environments.

1.3.3. Chapter 4. Hybrid teams in education

This chapter, submitted to The Internet and Higher Education (Elsevier - IHE, n.d.), examines how a telepresence robot impacts group conditions and student engagement among graduate students collaborating within hybrid classrooms. Focusing on a unique constellation of actors—hybrid teams composed of on-site and remote students—the study explores how service robots can address the challenges posed by physical separation in collaborative learning environments. Drawing upon team learning theory (van den Bossche et al., 2006), this study investigates how TEMI (Figure 1.3) a telepresence robot (TPR) with low autonomy but medium customization options influences essential group conditions - social cohesion, psychological safety, and group potency - that enable effective collaborative learning. The robot's role is best described as a facilitator - enabling physical embodiment and mobility for remote students to establish presence and engage naturally with on-site peers in collaborative learning activities.

Figure 1.3. Robot TEMI

Through a mixed-methods field study across 17 tutorial groups, combining longitudinal survey data of 156 students with 10 qualitative interviews, this research explores how a physical robotic presence shapes interactions between on-site and remote students. As an actor within the broader educational network, the telepresence robot's ability to navigate the physical classroom space introduces new possibilities for remote student participation and engagement. This unique context allows us to understand how technological actors can transform relationships and interactions within hybrid educational environments, extending beyond traditional video conferencing solutions, investigating how service robots, as a frontline service technology, facilitate interactions and transform relationships among actors in hybrid teams by augmenting remote students' capabilities and enabling them to establish a stronger physical presence while more naturally engaging in collaborative learning activities (De Keyser *et al.*, 2019; Raes *et al.*, 2020).

Moving from education to *healthcare*, Chapter 5 explores how service robots support both *people with intellectual disabilities (PwID)* and their *professional caregivers* in *long-term care settings*.

1.3.4. Chapter 5. Service triad in healthcare

This chapter, submitted to the *Journal of Medical Internet Research* (JMIR Publications, n.d.), investigates the implementation and sustained use of social robots in long-term care settings. Drawing upon the *NASSS framework* (Greenhalgh *et al.*, 2017) and *Meiland's model for adaptive implementation* (Meiland *et al.*, 2004), the chapter examines how Ivy (**Figure 1.4)**, a service robot with medium autonomy but high customization capabilities, creates value for both *PwID* and *healthcare professionals*. Central to this investigation is the understanding of *barriers* and *facilitators* that influence whether and how the robot becomes embedded in productive care environments. Ivy's role can be best described as an *assistant*, providing cognitive support, and fulfilling social needs for PWID and serving as a tool for healthcare professionals to enhance care delivery.

Figure 1.4. Robot Ivy

Through an analysis of 19 implementation cases across six care organizations, this research provides insights into the conditions necessary for the successful integration and sustained use of service robots in healthcare—more specifically, in long-term care. As actors within this complex healthcare network, both clients (PwID) and healthcare professionals play crucial roles in shaping how the robot becomes part of daily care practices. This implementation study offers unique insights into how service robots can be effectively integrated into existing care relationships while supporting both clients and healthcare professionals.

Moving from *micro-level implementation* to a *broader ecosystem perspective*, Chapter 6 examines how organizational and inter-organizational activities and strategies in *Service Robot-based innovation* enable service robots to create *Public Value*.

1.3.5. Chapter 6: Ecosystems in healthcare

This conceptual chapter, published in the *Journal of Product Innovation Management* (Wiley - JPIM, n.d.), explores how organizational and inter-organizational activities and strategies in *Service Robot-based innovation* enable service robots to create value. Building on *public value innovation* (PVI; Spanjol *et al.*, 2024), this research investigates how *ecosystems of public and private stakeholders* converge to develop and implement service robots in long-term care settings. Robot Ivy, introduced in Chapter 5, is revisited in Chapter 6 as an illustrative case to provide further insights

(**Figure 1.4**). The study proposes a *comprehensive conceptualization of service robots*, identifying key characteristics such as autonomy, aesthetics, assistive roles, and user interfaces that determine innovation management practices and value creation.

The chapter analyzes how *Service Robot-based innovation* for *Public Value* requires coordination across micro (user), meso (organizational), and macro (societal) levels of the *ecosystem*, as stakeholders take on different roles throughout various development stages. While previous chapters examined relationships between actors at the micro-level, this chapter broadens the lens to understand how networks of stakeholders across various levels must align to enable successful service robot implementation. This multi-level perspective provides a comprehensive understanding of how Service Robot-based innovation requires actors to perform certain roles and activities and transforms relationships between human actors across all ecosystem levels.

1.3.6. Chapter 7: Conclusion

The final chapter brings together the learnings of different actors and network constellations, each working with various types of service robots, employed for distinct purposes, and with varying levels of customization across diverse service settings. It begins by summarizing the key findings of each chapter, using Actor-Network Theory (ANT) to highlight the unique insights they offer to the service robot literature. This is followed by an exploration of overarching contributions at the thesis level, integrating findings across chapters to provide a cohesive perspective on HRI in real-world contexts, highlighting how robots performing different roles influence actors and reshape relationships between them. Additionally, it presents future research themes and managerial implications for service providers implementing service robots.

The structure of this thesis is visualized in **Figure 1.5**, which positions each chapter according to its analytical scope - ranging from micro-level interactions between customers, service robots and FLEs, through meso-level organizational dynamics, to macro-level ecosystem considerations - and its primary actor focus. Chapters 2 and 5 examine all actors in the service triad (Odekerken *et al.*, 2022) and are therefore positioned at the center of the triad. Chapters 3 and 4 investigate human-robot interactions (HRI) between robots and groups of customers, as well as hybrid teams of students, and are thus placed along the service robot–customer axis in the figure. Chapter 6 takes an ecosystem approach and investigates how service robots affect actors on the micro, meso and macro level. Additionally, the colors used for the chapters represented the service industries: hospitality in blue, education in orange, and healthcare in green.

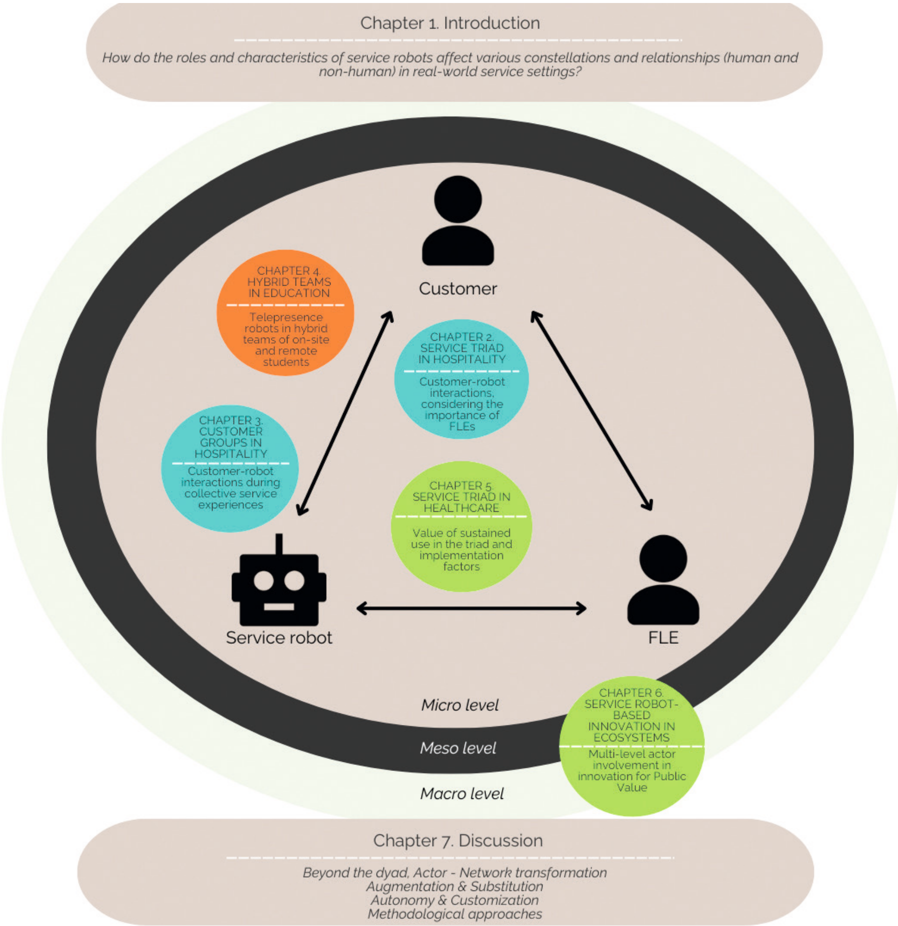


Figure 1.5. Overview visual of thesis structure

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CHAPTER 2

THE SERVICE TRIAD: AN EMPIRICAL STUDY OF SERVICE ROBOTS, CUSTOMERS AND FRONTLINE EMPLOYEES

In the case of this chapter:
Odekerken-Schröder, G., Mennens, K., **Steins, M.**, & Mahr, D. (2022). The service triad: an empirical study of service robots, customers and frontline employees. *Journal of Service Management*, Vol. 33 No. 2, pp. 246–292.

Double Award-winning paper:
- *The Robert Johnston 2022 Best Paper Award.* Awarded by Professor Jay Kandampully, Editor-in-Chief Journal of Service Management
- *Outstanding Paper Award - Literati Emerald Awards 2023.* Awarded by Sally Wilson, VP Publishing, Emerald Publishing Limited.

2.1. INTRODUCTION

In hospitality services such as restaurants, service triads consisting of technology, customers, and frontline employees (FLEs) are becoming more common (Li *et al.*, 2021). FLEs are more and more supported by a growing number of service robots that perform advanced frontline tasks involving social interactions with customers by talking with customers and serving food (Belanche *et al.*, 2020a; Tuomi *et al.*, 2020). In India, the restaurant "Robot" opened in 2017 as the country's first restaurant that uses robots to serve food (Raman, 2018). More recently, in China, the first robot restaurant complex employs more than 40 robots capable of serving and cooking over 200 dishes, and customers make their orders with robot waiters (Davis, 2020). In the USA, a group of 20 robotics engineers partnered with a Michelin-starred chef to found a restaurant in downtown Boston where human chefs are replaced by robots. The necessity to minimize human-to-human contact during the 2020/2021 COVID-19 pandemic has given robots an amplified platform (Davis, 2020; Odekerken-Schröder *et al.*, 2020). In Europe (the Netherlands), the fast casual dining Asian-style restaurant Dadawan introduced service robots to deliver trays to help human FLEs keep a safe distance when serving customers (Brady, 2020).

The competitive nature of hospitality services forces service providers to place the customer experience at the heart of strategic decision-making (Hunter-Jones, 2020; Kandampully *et al.*, 2018). It is typically challenging to combine service excellence and productivity (Wirtz and Zeithaml, 2018) as customer experiences imply hybrids of both human and technological interfaces (Singh *et al.*, 2019) could be the solution for realizing valued customer experiences in a cost-efficient way. Larivière *et al.* (2017, p. 239) introduced the concept of service encounter 2.0, which can be defined as "any customer-company interaction that results from a service system that is comprised of interrelated technologies (either company- or customer-owned), human actors (employees and customers), physical/ digital environments and company/customer processes." This novel perspective emphasizes the need to understand the service triad of customer – frontline employee (FLE) – technology (De Keyser *et al.*, 2019; Larivière *et al.*, 2017). In the case of service robots, the FLE can be either substituted or augmented by the service robot (Larivière *et al.*, 2017). Service research suggests that the service robot's role might be contingent on its level of anthropomorphism (Mende *et al.*, 2019; Van Doorn *et al.*, 2017), which can be defined as "the extent to which service robots are imbued with human-like characteristics, motivations, intentions, or emotion" (Xiao and Kumar, 2021, p. 7).

However, most of the existing research about frontline service robots is conceptual (e.g., Belanche *et al.*, 2020b; Huang and Rust, 2018; Van Doorn *et al.*, 2017; Wirtz *et al.*, 2018), with some notable laboratory studies in hospitality and tourism (e.g., Choi *et al.*, 2019; Ho *et al.*, 2020). In hospitality, the existing research mainly focuses on welcoming or greeting hotel customers, while the impact of service robot waiters in the customer frontline experience in restaurants remains largely under-researched (Zemke *et al.*, 2020). Lu *et al.* (2020) conclude that present research on service robots is fragmented, mostly conceptual in nature and misses out on the social complexity that determines technology adoption.

This study therefore addresses the knowledge gap that Rafaeli *et al.* (2017, p. 94) summarized as understanding "how to use the right technology for the right purpose in the right context by the right frontline employees for the right customers". More recently, specifically, Yoganathan *et al.* (2021) identified the knowledge gap related to service scenarios in the concurrence of service robots and human staff, reflecting our service triad of technology-customer-FLE.

The current article contributes to the literature by addressing the mentioned knowledge gaps by studying the interplay within the service triad of service robots, human FLEs and customers, and how it affects customer repatronage in hospitality. To draw insights, we employ a field study as well as a scenario-based experimental design with frontline service robots in a fast casual dining restaurant and refer to service robots as "system-based autonomous and adaptable interfaces that interact, communicate and deliver service to an organization's customers" (Wirtz *et al.*, 2018, p. 909). The insights enrich scholarly understanding of the interplay between the different actors in the service triad and the potential role the service robot and FLE can play in the service encounter 2.0 (De Keyser *et al.*, 2019; Huang and Rust, 2018; Larivière *et al.*, 2017).

Specifically, this research employs an exploratory observational study, a field study with $n = 108$ customers who interacted with a service robot in a fast casual dining restaurant and a scenario-based experimental study with $n = 361$ participants. The results show that customer repatronage is to a large extent determined by the utilitarian and hedonic value of the service robot, which in turn are driven by the humanoid characteristics of the service robot. In particular, we find that anthropomorphism exerts a stronger influence on the utilitarian value compared to the hedonic value of the service robot. The effect of the utilitarian value of the service robot is affected by the interaction quality of FLEs, such that lower utilitarian value can be compensated by high FLE interaction quality, implying potential augmenting roles for the service robot and FLE. In contrast, we find that higher utilitarian value of the service robot decreases the need for compensation through FLE interaction, suggesting the potential for highly functional service robots to substitute FLEs in fast casual dining settings.

Next, the theoretical background section elaborates about the main constructs in our service triad, comparing these insights to recent empirical studies on service robots in hospitality and beyond. Afterward, hypotheses are developed resulting in our conceptual model, followed by the methodology and results section derived from our field study and from our scenario-based experimental design. Finally, a discussion of the main findings and theoretical implications precede suggestions for future research. Managerial implications are provided for service managers responsible for employing tandems of service robots and FLEs, for robot engineers and designers and for policy makers.

2.2. THEORETICAL BACKGROUND

2.2.1. Service robots in hospitality services

While still being a nascent field, various scholars have recently studied the role of (service) robots in hospitality and tourism services. **Table 2.1** provides an illustrative overview of empirical studies using primary data sources. Almost all studies rely on laboratory experiments, while field data are rare, with some notable exceptions (e.g., Tuomi *et al.*, 2020). Anthropomorphism is an often-included construct, while only very few studies consider the service robot's social presence. Finally, the studies by Qiu *et al.* (2020) and Tuomi *et al.* (2020) take a service triad perspective by also including FLEs in their study. Extending prior research, our current field study includes both, anthropomorphism and social presence and investigates the interaction within the service triad of service robot – customer – FLE to further develop our understanding of service robots in FLE encounters. **Table 2.1** also presents a few illustrative empirical studies in other industries that address anthropomorphism, social presence and/or the service triad. The studies by Barrett *et al.* (2012) and Mende *et al.* (2019) acknowledge the service triad and study the effects of service robots on human employees in healthcare and other settings, whereas Heerink *et al.* (2008) focus on robot acceptance in healthcare. None of these studies include the related but distinct concepts of anthropomorphism and social presence, which can be seen as first and second-degree social responses (Lee *et al.*, 2006). In order to enhance our understanding of the interplay between these concepts on utilitarian and hedonic value, ultimately resulting in customer repatronage, this paper introduces an exploratory observation study, a field study and a scenario-based experimental design.

To introduce a conceptual model contributing to the nascent field depicted in **Table 2.1**, we summarize the ongoing debate on the core concepts of the conceptual model below.

Table 2.1. Literature overview: service robots in hospitality services and other industries

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Tussyadiah & Park (2018)	Online survey / Laboratory study	X			Intention to adopt service robots	Consumer's intention to adopt hotel service robots is influenced by human-robot interaction dimensions of: - Anthropomorphism - Perceived intelligence - Perceived security	Hotel
Ivanov, Webster & Garenko (2018)	Online survey / Laboratory study				Attitudes towards the use of robots in hotel services	- Respondents have positive attitudes towards the introduction of robots in hotels, but lower than towards service robots in general. - Respondents' attitude towards the use of robots in hotel services is influenced by: gender (male +), general attitude towards robots & perceptions of the experience provided by robots, advantages of robots and social skills of robots.	Hotel
Lu, Cai, & Gursoy (2019)	Online Survey / Laboratory study	X			Consumers' acceptance of service robots	- Performance efficacy, intrinsic motivation, facilitating conditions and emotions positively influence consumers' acceptance of service robots. - Human appearance may backfire for intelligent products due to the deterrence of perceived threats to human identity. Anthropomorphism negatively affects consumers' willingness to use robots in restaurants and retail stores.	Hospitality industry
Choi, Liu, & Mattila (2019)	Online survey / Laboratory study	X			Customer service evaluations	- Consumers respond more favorably to human service agents who use literal (vs. figurative) language, and due to the notion of anthropomorphism such an effect extends to service robots. - This language style effect is not observed among service kiosks as they lack humanlike features.	Hotel

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Ivanov & Webster (2019)	Online survey / Laboratory study				Perceived appropriateness and intention to use service robots	Most commonly approved usage of robots is perceived to be: - Information provision - Housekeeping activities - Processing bookings, payments and documents - The best indicator of willingness to use a robot in a hospitality setting is a person's general attitude towards robots.	Hospitality/ Tourism Industry
Qiu, Li, Shu, & Bai (2020)	Online Survey / Laboratory Study *Results from qualitative interviews used as input for conceptual framework*	X		X	The hospitality experience	- Robots being perceived as humanlike or intelligent positively affects customer-robot rapport building and the hospitality experience. - Customer-employee rapport building was found to mediate the relationship between robot attributes and the hospitality experience, but customer-robot rapport building was not.	Restaurant
de Kervenoael, Hasan, Schwob, & Goh (2020)	Online Survey / Laboratory Study *Structural equation modeling with data collected from semi-structured interviews*				Social robot usage intentions	- Visitors' intentions to use social robots stem from the effects of technology acceptance variables & service quality dimensions (perceived usefulness, perceived ease of use, service assurance, personal engagement and tangibles) leading to perceived value, and two further dimensions from human robot interaction (HRI): empathy and information sharing.	Hospitality Industry

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Ho, Tojib, & Tsarenko (2020)	Online survey / Laboratory study				Service experience evaluation	- Service recovery from the human staff and from the service robot resulted in similar service evaluations. - Customers evaluate their service experience less favorably when receiving service recovery from fellow customers in comparison to human staff and service robots.	Hotel
Belanche, Casaló, & Flavián (2020)	Online survey / Laboratory study	X			Customer behavioral intentions to use and recommend service robots	- Attributions mediate the relationships between affinity toward the robot and customer behavioral intentions to use and recommend service robots. - Customer's affinity toward the service robot positively affects service improvement attribution, which in turn has a positive influence on customer behavioral intentions. - Affinity negatively affects cost reduction attribution, which in turn has a negative effect on behavioral intentions. - Human-likeness has a positive influence on affinity.	Restaurant
Tuomi, Tussyadiah, & Stienmetz (2020)	Observations and semi-structured interviews / Field study			X	Role of service robots in relation to service production and delivery	The study reviews applications of robotics in actual hospitality service - Service robots either support or substitute employees in service encounters. - Service robots offer hospitality businesses a novel point of differentiation, but only if properly integrated as part of wider marketing efforts. - Automation of tasks, processes, and, ultimately, jobs has serious socioeconomic implications at both the micro level and macro level.	Hospitality industry

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Fan, Wu, Miao, & Matilla (2020)	Online survey / Laboratory study	X			Customer dissatisfaction after a service failure	- Technology anthropomorphism generally alleviates consumer dissatisfaction. Consumers show varying levels of dissatisfaction with a service failure caused by an anthropomorphic (vs. non-anthropomorphic) self-service machine depending on their levels of interdependent self-construal (high vs. low) and technology self-efficacy (high vs. low). The underlying mechanism is self-blame. - Consumers low in technology self-efficacy and low in interdependent self-construal tend to blame themselves more when facing a service failure	Hospitality/ Tourism Industry
Choi, Choi, Oh, & Kim (2020)	Online Survey / Laboratory study *Results from qualitative interviews with hotel staff were used as input*				Perceived service quality: - Interaction quality - Outcome quality - Physical service environment	- Understanding the influence of human–robot interaction from the viewpoint of hoteliers and guests. - Human staff services are perceived higher than the services of service robots in terms of interaction quality and physical service environment. However, no significant difference in outcome quality.	Hotel
Zhong, Sun, Law, & Zhang (2020)	Online survey / Laboratory study				- Attitude - Purchase intention - Purchase behavior	- Purchase intention and attitude of the experimental group (robot hotel service) was higher than the control group (traditional hotel service). - No effect found for purchase behavior.	Hotel

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Lin , Chi & Gursoy (2020)	Online survey / Laboratory study	X			Hospitality customers willingness to accept the use, and objection to the use of artificially intelligent devices	- Intention to use artificially intelligent devices is influenced by social influence, hedonic motivation, anthropomorphism, performance and effort expectancy, and emotions toward the artificially intelligent devices. - Anthropomorphism positively influences the effort expectancy of respondents. - Results are contingent on the type of hotel (limited-service hotel vs. full-service hotel).	Hotel
Jia, Chung & Hwang (2021)	Online Survey/ Laboratory study	X			Hotel visitors' satisfaction and purchase intention	- User satisfaction with service robots in a hotel had a positive impact on user satisfaction, attitude towards the hotel and room purchase intention. - Users were most likely to accept medium-human likeness robots and least likely to accept high–human likeness robots.	Hotel
Lu, Zhang & Zhang (2021)	Online Survey / Laboratory study	X	X		Consumption Outcomes: - Service encounter evaluation - Revisit intentions - Positive WOM intentions	- Robotic service staff's human-like attributes are key determinants of consumption outcomes. - Humanlike voice increases service encounter evaluation and behavioural intentions (revisit intentions and WOM intentions). - Humanlike language positively affects service encounter evaluation. - Positive emotion accounts for the positive effect of human-like voice. - Perceived credibility and positive emotion explain the language effect.	Restaurant

2

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Other Industries							
Heerink *et al.* (2008)	Survey after actual experience with robot / Field study		X		Robot acceptance	Social abilities contribute to the sense of social presence when interacting with a robotic companion and this leads, through higher enjoyment to a higher acceptance score.	Elderly-Healthcare
Barrett *et al.* (2012)	Divers- site visits, observations, formal interviews, informal discussions, and publicly available documents / Field study			X	Impact of robots on hospital pharmacies	- Benefits for employees include that (a) robots facilitates team collaboration; (b) free up time for the employees to engage in specialized and customer-centered work; (c) increase employees' institutional legitimacy (i.e., employees reinforcing their role and status in the organization) and (d) employees can upgrade their technical skills as authorized caretakers of the robots - Potential negative employee consequence include (a) a loss of autonomy and frustration due to lack of interaction with customers; and (b) employees feel a disruption to their normal routine when robots bring changes to their jobs	Healthcare

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Fan, Wu & Mattila (2016)	Quasi-experimental design / Laboratory study	X			Customers' switching intentions following a robotic service/ self-service technology machine failure	- Anthropomorphism negatively influences customer's switching intentions; e.g., a human-like voice encourages customers to continue using the machines (rather than switching to a human). - Powerful customers exhibit higher switching intentions when a machine has an anthropomorphic (vs robotic) voice in the absence of other customers, yet they show an opposite tendency in the presence of other customers. Therefore, the presence of other customers moderates the voice type effects on powerful customers' switching intentions. - Powerless customers demonstrate lower switching intentions when they experience a service failure with a human-like (vs robotic) SST, regardless of the absence or presence of other customers)	Retail

Table 2.1. Continued

Citation	Research Method / Type of Study	Anthro-pomor-phism	Social Presence	Service triad: FLE considered	Outcome variables	Findings	Context
Mende *et al.* (2019)	Online survey / Laboratory study	X		X	Customer experience after interacting with humanoid service robots	- Interaction with humanoid service robots elicits compensatory responses compared to interactions with human employees - Higher compensatory consumption poses opportunity to use service robots for upselling - Higher compensatory consumption is due to greater consumer discomfort, i.e., eeriness and a threat to human identity - Consumers respond more favorably to humanoid service robots that are less (vs. more) human-like - Compensatory responses are (1) mitigated when consumer-perceived social belongingness is high, (2) attenuated when food is perceived as more healthful, and (3) buffered when the robot is mechanized (rather than anthropomorphized)	Across service contexts
Van Pinxteren *et al.* (2019)	On-site Survey / Experimental field study	X			Trust in humanoid robots	- Anthropomorphism drives trust, intention to use and enjoyment - If customers are comfortable with robotic interactions, human-like appearance of robots is more effective than social functioning features - If they are uncomfortable this effect is reversed	Public service
Current study	Study 1: Online survey after actual service robot experience / Field study Study 2: Scenario-based experimental design	X	X	X	Customer Repatronage	*See findings*	Restaurant

2.2.2. Anthropomorphism

The first concept is anthropomorphism. Anthropomorphism describes a main feature of humanoid robots and has its roots in the Greek words "*anthropos*" (human) and "*morphe*" (shape or form). It originally refers to the phenomenon by which nonhuman entities are given human shape or form (Wan and Aggarwal, 2015). Social psychology expands the view on anthropomorphism to the "tendency to imbue the real or imagined behavior of non-human agents with human-like characteristics, motivations, intentions, or emotions" (Epley *et al.*, 2007, p. 864), offering a foundation for research on service robots (Xiao and Kumar, 2021).

While marketing has found anthropomorphism to increase product and brand liking (Aggarwal and McGill, 2012), it is unclear whether anthropomorphism in a frontline service triad including service robots enhances customers' repatronage. Contemporary service research acknowledges the importance of the human tendency to anthropomorphize robots (Mende *et al.*, 2019; Van Doorn *et al.*, 2017), but the question remains whether customers' anthropomorphism of robots facilitates or constrains use intention (Blut *et al.*, 2021).

One stream of research argues that anthropomorphizing a nonintelligence product (e.g., service robot) is a useful strategy to increase consumer preferences because the human intentions and emotions are associated with intelligence and competence in task performance (Wan and Aggarwal, 2015). Taking this perspective would favor the use of anthropomorphized robots in the service triad of technology-customer-FLE (Duffy, 2003; Reed *et al.*, 2012). A recent meta-analysis conducted by Blut *et al.* (2021) demonstrates that anthropomorphism is in the eye of the beholder rather than referring to the extent to which firms design robots as humanlike.

A second stream of research emphasizes the paradoxical effect that increased anthropomorphism can result in consumers experiencing discomfort such as feelings of eeriness or a threat to their human identity and feelings of human inadequacies (Lu *et al.*, 2019; Mende *et al.*, 2019; Reed *et al.*, 2012). This view is in line with the uncanny valley theory postulating that the customer's affinity for a robot does not continuously increase with its human likeness as customers may find a highly humanlike robot creepy and uncanny (Mori, 1970; Mori *et al.*, 2012). Strong anthropomorphic qualities may also lead to overly optimistic expectations about a robot's abilities, which can be disappointing (Wirtz *et al.*, 2018). Fostering scholarly understanding on the service triad technology-customer- FLE and the role of anthropomorphism is an important research direction (Van Doorn *et al.*, 2017).

2.2.3. Social presence

A related, but distinct concept is social presence. In virtual reality studies, Heeter (1992) indicates that presence consists of the three dimensions personal presence (extent to which you feel you are in a virtual world), environmental presence (the extent to which the environment seems to know you are there) and social presence (the extent to which someone or something, like computer generated beings, believes you are there). Social presence has the most implications for human-robot-interactions (HRI) because it is the ultimate aim of designing socially, interactive robots (Lee *et al.*, 2006).

Origins of social presence of robots can be found in symbolic interactionism and social psychological theories of interpersonal communication (Biocca *et al.*, 2003). The emphasis of social presence is on the agent's capacity for social interaction and verbal or nonverbal cues in communication. Therefore, physically present (e.g., sculptures) would not suffice to be perceived as socially present (e.g., beings) as social presence is mainly based on the sense that one has "access to another intelligence" (Biocca *et al.*, 2003).

Media equation theory argues that customers equate social robots with real social actors as they rely on their natural tendency of accepting things at their face validity and react to robots as if they were human (Lee *et al.*, 2006). The computers are social actors (CASA) research paradigm is derived from media equation theory and is frequently used to understand HRI. CASA is based on the idea that when confronted with an anthropomorphic robot, (a) humans respond to the robot socially, (b) humans are persuaded by the imitation of human characteristics of the robot and (c) humans do not process the fact that the robot is not a human (Lee *et al.*, 2006).

Although in service research Van Doorn *et al.* (2017, p. 43) refer to *automated* social presence (ASP) as "the extent to which technology makes customers feel the presence of another social entity", the original construct of social presence can be either a human or artificial intelligence evoking reactions to social cues (Biocca *et al.*, 2003). Therefore, in the current study, we focus on social presence. For engineers and designers of social robots, increasing the experience of social presence is typically a design goal (Biocca *et al.*, 2003). Recently, Gambino *et al.* (2020) summarize that engineers and designers aim for natural forms of social interaction between service robots and users to minimize the cognitive effort it takes human actors to use service robots.

2.2.4. Utilitarian and hedonic value

Anthropomorphism and social presence are expected to result in utilitarian and/or hedonic value. Motivation theory suggests that customers behave to satisfy their needs. Rooted in motivation theory, the more recent self-determination theory (SDT) provides a substantive basis for human behavior, distinguishing between extrinsic (utilitarian/instrumental) and intrinsic (hedonic) motivations (Deci, 1975; Deci and Ryan, 1985; Ryan and Deci, 2001). In marketing, Hirschman and Holbrook (1982) introduced a more experiential view of consumption, including hedonic reasons to the more traditional utilitarian reasons for a purchase. Likewise, contemporary studies investigate the effect of utilitarian and hedonic value on repeat patronage (Hepola *et al.*, 2020) or as dimensions of experiential value of robots in the service encounter (Wu *et al.*, 2021).

This study focuses on the value of service robots in hospitality which is inherent to the service perspective implying that "value is created collaboratively in interactive configurations of mutual exchange" (Vargo and Lusch, 2008, p. 145). The concept of value has its origins in other disciplines. Sociology, psychology, and economics, for example, have a long tradition of investigating instrumental and hedonic dimensions of attitude (Voss *et al.*, 2003).

In restaurants, it is also commonly known that the value customers perceive is not merely based on utility (utilitarian) but to a large extent also on gratification (hedonic) (Noone *et al.*, 2009). The distinction between utilitarian and hedonic value also found its way into recent research on service robots. In their study on service robots' value co-creation and value co-destruction potential, Čaić *et al.* (2018) argue that service robots offer new value propositions, where value is created when engaging in the service leaves actors better off relative to their initial conditions. Demonstrated in the context of elderly care, socially assistive robots positively impact both utilitarian (e.g., effectiveness) as well as hedonic value (e.g., fun; Čaić *et al.*, 2019).

2.2.5. FLE interaction quality

Taking a service triad perspective consisting of service robots, customers and FLEs, implies that the interaction quality of FLEs plays a role during the service encounter. The nature of interactions is widely seen as the nucleus for value creation during the service encounter exercising a strong impact upon customer responses. Early, service researchers positioned service encounters as role performances in which the so-called service script would contain information about the role set related to one's own expected behavior as well as to the expected complementary behavior of others reflecting the prototypical service experience (Hui and Bateson, 1991; Solomon *et al.*, 1985).

While service research evolved, scholars in marketing and organizational behavior were giving increasing attention to the personal interaction between the customer and the FLE of service businesses. The service encounter became a focal point in consumer evaluations of the entire service organization and implied a great opportunity for a service firm to customize the delivery of its service to help the individual consumer. This customization opportunity is a potential source of competitive advantage for the service firm, which can lead to favorable service quality evaluations by consumers (Bettencourt and Gwinner, 1996; Bitner *et al.*, 1990; Bock *et al.*, 2016).

FLE performance quality is concerned with how the service is delivered, especially emphasizing the demand for emotional labor. For example, a service employee is expected to express positive emotions when interacting with a customer and act in a way to build trust, demonstrate promptness and reliability, and give a sense of personal attention (Singh, 2000). Therefore, we define quality of FLE interaction as consumers' perception of the interpersonal interactions with human employees that take place during service delivery (cfr. Brady and Cronin, 2001) and the FLEs willingness to help (cfr. Singh, 2000). In turn, a high-quality performance is thought to enhance customer intentions (Singh, 2000).

In the 2017 special issue on organizational frontlines, service scholars acknowledge the emerging role of technology resulting in a triadic (technology-customer-FLE) rather than a dyadic service encounter. Research recognizes that the human connection between staff and consumers can be challenging in technology-infused service interactions, and there will be a greater desire for employees who can connect with customers (Rafaeli *et al.*, 2017).

Along the continuum ranging from technologies that replace FLEs to those that augment FLEs to provide service, smart technologies (e.g., service robots) provide value and an important question is how such technologies can be leveraged and integrated in the triadic service encounter technology-customer-FLE to create value. Marinova *et al.* (2017) define frontline interactions to also include interactions between a customer and an artificial intelligence-powered machine, which connects the customer with the organization by replacing or augmenting FLEs to coproduce value. In a similar line, Singh *et al.* (2017) describe organizational frontline as interactions and interfaces at the point of contact between an organization and its consumers that promote, facilitate or enable value creation and exchange. They explicitly argue that interfaces refer to the characteristics of modes, agents (or robots), artifacts and servicescapes that serve as the medium for the contact between the customer and the organization, acknowledging the role of service robots.

Most recently, Yoganathan *et al.* (2021) argue that robots and human staff can deliver services in collaboration. The interaction quality between robots and FLE in a service setting is expected to influence consumer service outcomes differently. Knowledge on the conditions under which service robots-FLE collaboration generate positive or negative outcomes is still scarce (Larivière *et al.*, 2017). For that reason, the current study investigates the role of FLE interaction quality in the triadic service encounter including service robots, customers and FLE.

2.2.6. Customer repatronage

The knowledge gap on how repatronage intentions in the service triad evolve is central to our study. In the contemporary service industry, facing numerous alternative offerings, service providers first encourage consumers to make an initial purchase, and in a second stage, they encourage existing customers to revisit or repurchase, based on their previous experiences (Ho and Chung, 2020). In highly competitive hospitality services such as restaurants, repatronage is an important loyalty indicator (Wirtz and Mattila, 2004). Customer repatronage reflects the likelihood that a customer will visit the restaurant again (Atulkar and Kesari, 2017). The service robot literature recently studied the effect of human likeness of the robot service (Lu *et al.*, 2021) and customer satisfaction with service robots (Jia *et al.*, 2021) on repatronage intentions (e.g., revisit intentions and purchase intentions) resulting in mixed findings.

2.3. HYPOTHESES DEVELOPMENT AND CONCEPTUAL MODEL

Based on the concepts discussed in the literature review, this section will develop the hypotheses underlying our conceptual model.

As discussed, in this study, anthropomorphism refers to humanoid thoughts and emotions, whereas social presence refers to the sense of being with another. Heeter (1992) argues that the characteristics of the agent/service robot (anthropomorphism) affect the strength of the sense of social presence that is created.

Anthropomorphization can be seen as a "*first degree social response*", referring to the identification of fundamental human characteristics. Social presence, on the other hand, can be seen as a "*second degree social response*," implying more subtle and complicated attitudinal and behavioral responses after identifying fundamental human characteristics (Lee *et al.*, 2006). HRI research argues that the user's response to anthropomorphism precedes the user's realization of the robot's presence (Lee *et al.*, 2006), and its positive effects are widely supported in the literature (Kim *et al.*, 2013; Mende *et al.*, 2019; Van Doorn *et al.*, 2017). Therefore, we expect also for our hospitality context that the more robots are perceived as humanlike, the stronger customers feel a social presence triggering social interaction and hypothesize the following:

H1. Service robot's anthropomorphism will exhibit a positive relationship with the service robot's social presence.

Based on our review of the literature on service robots in hospitality services, we observe a recent interest in the role of anthropomorphism on customer outcome variables (see **Table 2.1**). Existing studies provided mixed evidence as to the role of anthropomorphism. In contrast to the assumption that humanlike service robots positively impact consumer preference, Lu *et al.* (2019) argue that humanoid cues might backfire due to the perceived threat to human identity. In the customer service context, customers are likely to perceive utility and/or gratification in their interaction with a service robot. Utilitarian value suggests that customers will have more confidence in the accuracy and consistency of the service provided, whereas service robot's hedonic value relates to fun and entertainment (Arnold and Reynolds, 2003; Lu *et al.*, 2019; Ryan and Deci, 2001). Service providers implement anthropomorphic service robots to create value and encourage customer loyalty (Blut *et al.*, 2021; Zemke *et al.*, 2020). Therefore, for our context of hospitality services, we expect that being perceived as a human as the *first degree of social response* (anthropomorphism) translates into the provision of the core service such as serving food and drink rather than into entertaining guests. Our assumption is that in the case of consistently serving food and drinks (utilitarian), anthropomorphism is not perceived by customers as a threat to human identity, while entertaining guests (hedonic) would. Hence, we expect a stronger impact of anthropomorphism on utilitarian rather than on hedonic value perceptions and hypothesize the following:

H2. Service robot's anthropomorphism exhibits a stronger positive relationship with the service robot's utilitarian value than with its hedonic value.

In hospitality, customers frequently have high expectations of being with another other and having pleasant social interactions (Fuentes-Moraleda *et al.*, 2020). Based on laboratory experiments in communication research, Lee *et al.* (2006) empirically demonstrate that social presence has a positive impact on utilitarian value (e.g., consistency and accuracy) and on hedonic value (e.g., fun and entertainment). In their field studies, Čaić *et al.*, 2019 demonstrate that automated social presence has a positive effect on both hedonic (e.g., fun) as well as on utilitarian value (e.g., effectiveness) in the context of socially assistive robots in an elderly care setting. We argue more specifically for our context of service robots in hospitality that social presence triggers social interaction between customers and the hospitality provider and – as *second degree of social response* (social presence) – seems to match the auxiliary services (e.g., entertainment and fun) rather than to the core service provision (e.g., serving food and drinks). Therefore, we expect a stronger impact of social presence (Biocca *et al.*, 2003) on hedonic rather than on utilitarian value perceptions and hypothesize the following:

H3. Service robot's social presence exhibits a stronger positive relationship with the service robot's hedonic value than with its utilitarian value.

The decision whether or not to return to a service provider typically depends on the utilitarian hedonic value the customer perceives (Atulkar and Kesari, 2017; Hepola *et al.*, 2020). In retailing, it is to be expected that utilitarian value (rather task-oriented) results in repatronage as higher levels of excitement (e.g., fun and enjoyment) will do too (Wakefield and Baker, 1998). We apply a similar reasoning to service robots in hospitality, assuming that if customers perceive service robots to offer utilitarian and hedonic value, this will encourage them to repatronage the restaurant. Therefore, we hypothesize the following:

H4. Service robot's utilitarian value exhibits a positive relationship with customer repatronage intentions.

H5. Service robot's hedonic value exhibits a positive relationship with customer repatronage intentions.

Moderating hypotheses

Contemporary service research views augmentation from the perspective that technology enhances human actors (De Keyser *et al.*, 2019; Larivière *et al.*, 2017; Marinova *et al.*, 2017). Taking a service triad perspective, we reason that actors can augment each other's tasks in the service encounter, implying that a service robot can augment FLEs or that FLEs can augment service robots. Augmentation involves assisting and complementing other actors in the service triad to perform their tasks better and achieve their goals in the service encounter.

Service triads, consisting of service robots, customers and FLEs by definition imply that the physical encounter between customer and FLE is augmented by technology (De Keyser *et al.*, 2019; Hilken *et al.*, 2017). In order to guide service managers in setting-up these service triads, an increased understanding is needed as to how human and nonhuman actors work in tandem.

Previous studies show that customer needs for a human touch can be especially relevant when handling failures (De Keyser *et al.*, 2015). In case the service robot's utilitarian or hedonic value is low, which can be thought of as some kind of failure, we expect the FLE to compensate for this failure and augment the service robot's value resulting in repatronage intentions.

More specifically, for our context of hospitality service, triads with a strong emphasis on the provision of the core service such as serving food and drinks (utilitarian elements) we expect that high-quality interactions with FLEs can augment lower levels of service robot utilitarian value. In other words, customers in the service triad who lack the robot's accuracy and consistency feel supported by employees' efforts in the interaction (Stein and Rameseshan, 2019) and decide to revisit the venue. In a similar vein, for our people-oriented service encounter (Li *et al.*, 2021) in a restaurant that people typically visit for enjoyment (hedonic elements), we expect that high-quality interactions with FLEs can also augment lower levels of service robot hedonic value (Qiu *et al.*, 2020).

Summarizing, a positive customer perception of interpersonal interactions with FLEs (Brady and Cronin, 2001) and their demonstrated willingness to help (Singh and Sirdeshmukh, 2000) can increase customer repatronage intentions in cases when the service robot functional performance and entertainment are relatively low. Therefore, we hypothesize the following:

H6. Quality of FLE interactions augments the service robot's utilitarian value resulting in customer repatronage intentions.

H7. Quality of FLE interactions augments the service robot's hedonic value resulting in customer repatronage intentions.

The conceptual model is visualized in **Figure 2.1**.

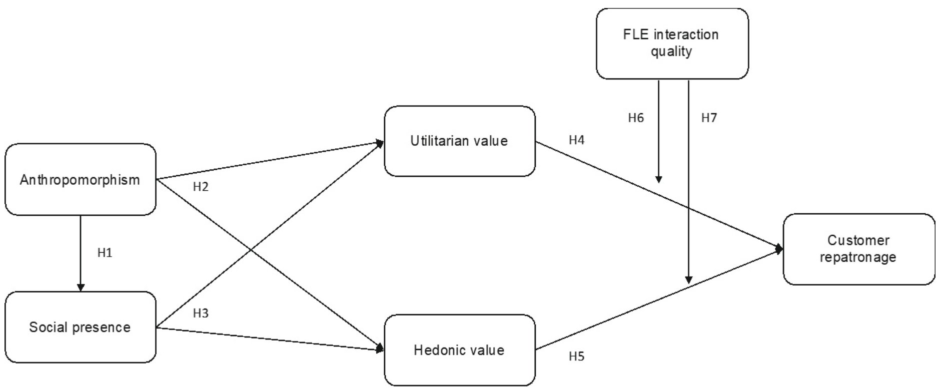

Figure 2.1. Conceptual Model

2.4. STUDY 1 – METHOD

2.4.1. Empirical context

Our empirical context reflects a triadic encounter consisting of service robots – FLEs – customers. It entails a fast casual dining restaurant in Europe that offers Asian-style dining. The restaurant promises worldly food for small town prices and strives for revenue management, described by Noone *et al.* (2009) as reducing service encounter duration to welcome more customers and generate more revenues during high demand periods. The restaurant can typically be recognized by a long waiting line outside that customers gladly accept in return for an affordable and fast casual dining experience.

In the COVID-19 pandemic, this restaurant implemented two frontline service robots, resulting in a service triad of service robots, FLEs and customers. First, these service robots minimized human-to-human contact and, thereby, the risk of spreading the virus (Davis, 2020). Second, substituting human FLEs with service robots increased the maximum number of customers that could be seated as the particular government only allowed a maximum number of people in a restaurant at the same time, including staff. Third, this limited amount of customers allowed, (normal maximum capacity of the restaurant is approximately 300 customers) created a smaller setting which was an excellent environment to experiment with the service robots. Both service robots – Amy and Akatar, displayed in **Figure 2.2** – can be considered humanoid, which refers to a robot with human-like features (Mende *et al.*, 2019). Namely, they both have a face and a name (van Pinxteren *et al.*, 2019). Moreover, they can communicate unilaterally with the customers with a humanlike voice (they can speak to the customers, but they do not respond) (Złotowski *et al.*, 2015). Each service robot has its own shape that supports a distinctive set of tasks: Amy serves drinks and picks up the empty glasses, and Akatar delivers dishes from the kitchen to the customer's table.

Figure 2.2. Field study robots Amy (left) and Akatar (right)

2.4.2. Exploratory field observations

To gain a better understanding of this triadic service encounter, data collection started with a field observation during the first three days of the implementation of the service robots (June 3 until June 5, 2020). Field observations typically clarify and focus initial ideas and give concrete insights into the context and the people involved (Goodman *et al.*, 2012). A semi-structured observation protocol was followed that allowed for deviation and comments, allowing a rich description of the hospitality context at hand (Denzin, 2001). In total, data were collected during 9 hours of field observation, spread across three researchers. Field observations in the restaurant were covert, with permission of the restaurant owner, to ensure that interactions with the service robot were not influenced by the observer, avoiding the Hawthorn effect (Jones, 1992). The field observation enabled the research team to get a rich understanding of the service triad and resulted in two main insights. First, the field notes uncovered dyadic and triadic interactions in the triad "service robot-customer-FLE". Second, the field notes revealed two potentially different benefits of the service robot: (1) utilitarian value: service robot serves food and drinks to the customers and by doing so also offers functional support to the FLE and (2) hedonic value: service robot offers entertainment and enjoyment to customers, which can for example be observed by customers taking selfies with the service robot. These insights were used as an input for the survey development of our field study and subsequent scenario-based experimental design.

2.4.3. Sample and measures

Based on extensive discussions with the restaurant owner and store manager, it became clear that the typical segment of the restaurant consists of relatively young customers such as students, young couples, and families with young kids. Therefore, we decided for a QR-code that quickly and efficiently converse the survey URL to customers. The main reasons underlying this decision are: (1) the free Internet access in the restaurant, (2) the high likelihood of customers bringing their smartphone, (3) aim for minimal human-human interaction in the COVID-19 pandemic and (4) environmental friendliness.

Before the first day of our data collection, we prepared a podcast with instructions for the team of human FLEs. The store manager shared this podcast with his team via the team's WhatsApp group to emphasize the importance of timing of showing the flyer with QR-code (i.e., after customers completed their main course to make sure they experienced FLEs and service robot interactions). In addition to the podcast, we also provided instruction flyers for the team including the steps they had to recall in the data collection stage. These flyers were located at various backstage locations in the restaurant, reminding the human staff of the research taking place.

The FLEs showed a plasticized flyer (**Appendix 2.1**) to customers after they finished their main course. This ensured that customers did experience the triadic service encounter.

As an incentive, the customers were offered a free homemade iced tea in return for completing the online survey on their mobile device. Data collection took place over the course of one month, from September 14 to October 14, 2020. In total, 124 customers who interacted with the service robot completed the survey, resulting in a final dataset of 108 responses after elimination of incomplete answers. Of the respondents, 70.8% were female, and in terms of age, 81.5% fell within the range of 18 and 34 years. In addition, 69.4% of the sample consisted of repeat customers (i.e., had visited this fast casual dining restaurant before). The respondents mainly visited the restaurant with friends (62%), their partner (21.3%) or family (13.9%).

All items in the survey were adapted from existing measurement scales, which were partially reduced to fit our context of fast casual dining. The items were assessed on a seven-point Likert scale (1 = "strongly disagree", 7 = "strongly agree"). Our dependent variable, customer repatronage intention, was captured by the respondent's intention to revisit the restaurant within the next six months and was measured with a two-item scale adapted from Maxham and Netemeyer (2002). The moderating variable, FLE interaction quality, was adapted from three items of Brady and Cronin's (2001) interaction quality construct. The service robot's utilitarian and hedonic value were both assessed based on four items adapted from the recently developed service robot adoption willingness scale (Lu *et al.*, 2019). Specifically, the utilitarian value construct was composed of items focusing on the service robot's accuracy and consistency in performance, whereas hedonic value was assessed through customer's fun and entertainment experienced while served by the robot (Lu *et al.*, 2019). The service robot's social presence comprised of five items adapted from Lee *et al.* (2006). Lastly, anthropomorphism was captured by five items developed by Lu *et al.* (2019). To answer the questions related to the service robot, we asked the respondents to answer these questions while keeping in mind the robot they interacted with the most. We included this baseline service robot as a control variable in our PLS model. A complete list of the items and their factor loadings can be found in **Table 2.2**, whereas their scale reliabilities are displayed in **Table 2.3**.

2.4.4. Data analysis

We turn to partial least squares structural equation modeling (PLS-SEM) to test our hypotheses. PLS-SEM is an estimation technique based on OLS regressions. It focuses on the prediction of a specific set of hypothesized relationships that maximizes the explained variance in the dependent variables, similar to OLS regressions (Hair *et al.*, 2016). This makes PLS-SEM particularly useful for success driver studies (Hair *et al.*, 2011). The decision to apply this method of analysis was driven by two main reasons. First, PLS-SEM can handle small sample sizes of less than 200 respondents (Bacile, 2020; Chin, 1998; Hair *et al.*, 2012). Hair *et al.* (2016) provide minimal sample size requirements to detect various R^2 values at a 5% significance level while taking the complexity of the PLS path model into account. The maximum number of arrows pointing at a construct in this study is three, so we need at least 37 respondents to pinpoint R^2 values of at least 0.25 at a 5% significance level. Thus, we can conclude that our sample size of 108 is sufficiently large. Second, the method is nonparametric in nature and can therefore deal with nonnormal data (Chin, 1998; Hair *et al.*, 2016). Hair *et al.* (2012) recommend performing Shapiro–Wilk or Kolmogorov–Smirnov tests to evaluate whether data are normally distributed. Both tests in SPSS indicate that our anthropomorphism, service robot's hedonic value, FLE interaction quality and customer repatronage variables are non-normally distributed. Additional checks for skewness and kurtosis (Hair *et al.*, 2016) confirm that our data are non-normally distributed. For these reasons, we use PLS-SEM. More specifically, SmartPLS

3.3.2 software (Ringle *et al.*, 2015) was applied to conduct the analyses. We used the standard, recommended algorithm and settings, and administered case-wise deletion for missing variables.

Since the data from both our dependent and independent variables come from the same source, common method bias could be a potential threat (Podsakoff *et al.*, 2003). To evaluate the extent to which our data suffers from common method bias, we employ the procedure suggested specifically for PLS-SEM research by Kock (2015). As our estimations indicate that our highest VIF is 1.73, we can confirm our VIF values do not exceed the 3.3 threshold, suggesting that common method bias is not a concern for this study. In the next section, we first evaluate our measurement model, which attaches manifest variables to their latent variables. After that, we test the relationships between the latent variables by assessing the structural model (Fornell and Larker, 1981; Hulland, 1999).

Table 2 2. Items and factor loadings

Construct (source)	Items	Standardized loadings
Service robot anthropomorphism (Lu *et al.*, 2019)	(1) The robot has a mind of its own	0.85
	(2) The robot has consciousness	0.90
	(3) The robot has its own free will	0.92
	(4) The robot experiences emotions	0.90
	(5) The robot has intentions	0.73
Service robot social presence (Lee *et al.*, 2006)	(1) I feel as if I was interacting with an intelligent being	0.86
	(2) I feel as if I was accompanied by an intelligent being	0.84
	(3) I was involved with the robot	0.82
	(4) I feel as if I was responding to the robot	0.82
	(5) I feel as if I and the robot were communicating to each other	0.85

Table 2 2. Continued

Construct (source)	Items	Standardized loadings
Service robot utilitarian value (Lu *et al.*, 2019)	(1) The robot is more accurate than human employees	0.76
	(2) Information provided by the robot is more accurate with less human errors	0.90
	(3) The robot provides more consistent service than human employees	0.87
	(4) Information provided by the robot is more consistent	0.72
Service robot hedonic value (Lu *et al.*, 2019)	(1) I have fun interacting with the robot	0.91
	(2) Interacting with the robot is fun	0.90
	(3) Interacting with the robot is entertaining	0.82
	(4) The actual process of interacting with the robot is pleasant	0.79
FLE interaction quality (Brady and Cronin, 2001)	(1) Overall, I'd say the quality of my interaction with this restaurant's employees is excellent	0.88
	(2) I would say that the quality of my interaction with this restaurant's employees is high	0.92
	(3) The attitude of this restaurant's human employees demonstrates their willingness to help me	0.90
Customer repatronage intentions (Maxham III and Netemeyer, 2002)	(1) I expect to eat at this restaurant again in the next 6 months	0.94
	(2) I am certain that I will be eating at this restaurant again in the next 6 months	0.96

Table 2.3. Means standard deviations, correlations and reliability estimates

Construct	Mean	SD	AVE	CR	α	1	2	3	4	5	6
1. Anthropomorphism	3.34	1.69	0.75	0.94	0.91	*0.86*					
2. Social presence	4.31	1.56	0.70	0.92	0.89	0.65	*0.84*				
3. Utilitarian value	3.86	1.45	0.67	0.89	0.83	0.71	0.65	*0.82*			
4. Hedonic value	4.97	1.49	0.73	0.92	0.88	0.50	0.58	0.56	*0.85*		
5. FLE interaction quality	6.14	0.96	0.81	0.93	0.89	0.17	0.30	0.05	0.18	*0.90*	
6. Customer repatronage	5.88	1.57	0.90	0.95	0.89	0.33	0.39	0.24	0.23	0.48	*0.95*

Note(s): All constructs were measured on seven-point interval scales; SD = standard deviation; AVE = average variance extracted; CR = composite reliability; α = Cronbach's alpha. The square root of the average variance extracted for each construct is indicated in *italics* on the diagonal of the correlation matrix

2

2.5. STUDY 1 - RESULTS

2.5.1. Measurement model - validity and reliability

To ensure construct reliability, we check the item loadings, composite reliability and Cronbach's alpha values. First, for individual item reliability, we investigate the loadings. A generally accepted heuristic is that item loadings should be 0.7 or higher (Hair *et al.*, 2016). All our items exceed this threshold. For construct reliability, Hair *et al.* (2016) detail that the composite reliability and Cronbach's alpha values should exceed 0.7. As **Table 2.3** shows, construct reliability was established with strong composite reliability values ranging from 0.89 to 0.95 and Cronbach's alpha ranging from 0.83 to 0.91.

The AVE values for all constructs highly exceed 0.50 (see **Table 2.3**), indicating sufficient levels of convergent validity (Bagozzi and Yi, 1988; Hair *et al.*, 2016). To ensure discriminant validity, we follow both the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio criterion. For the Fornell-Larcker criterion, each construct must share more variance with its own measures than with any of the other constructs. This is reflected by a higher square root of the AVE for each construct compared with its correlations with other constructs (Fornell and Larker, 1981; Hair *et al.*, 2016). In addition, the square root of the AVE should not be lower than 0.7 (Chin, 1998). As **Table 2.3** shows, all constructs meet these criteria. Following the HTMT ratio criterion, the HTMT values for all pairs of constructs should be below 0.85 (Voorhees *et al.*, 2016). The HTMT values for our constructs range from 0.07 to 0.81 and are below the accepted threshold. Lastly, we can confirm that multicollinearity was not a threat to the measures as none of the variance inflation factor values exceeded the threshold level of 5 (Hair *et al.*, 2016).

To evaluate the predictive relevance of the model, we examine the effect size and explained variance of the endogenous constructs. **Table 2.4** indicates the R^2 values of the endogenous constructs range from 0.31 to 0.57, all exceeding the commonly accepted thresholds set by Falk and Miller (1992), Chin (1998) and Hair *et al.* (2011). In addition to the R^2, it is increasingly encouraged to report the f^2 effect sizes (Hair *et al.*, 2016). The f^2 effect sizes for the supported hypotheses range from 0.04 to 0.73 and, thereby, vary from small to large effects (Hair *et al.*, 2016). As such, the model's predictive relevance is supported.

Table 2.4. Results of hypotheses testing and explained variance

Hypothesized relationships	Standardized path coefficient	Hypothesis supported or not supported	R^2 (construct)
H1: Anthropomorphism → Social presence	0.65^{***}	Supported	0.42 (Social Presence
H2: Anthropomorphism → Utilitarian value stronger than Anthropomorphism → Hedonic value	0.49^{***} Utilitarian value 0.21^{*} Hedonic value	Supported	0.57 (Utilitarian value)
H3: Social presence → Hedonic value stronger than Social presence → Utilitarian value	0.33^{***} Utilitarian value 0.45^{***} Hedonic value	Not supported	0.36 (Hedonic value)
H4: Utilitarian value → Customer repatronage	0.23^{*}	Supported	0.31 (Customer repatronage)
H5: Hedonic value → Customer repatronage	NS	Not supported	
H6: Moderation: FLE interaction quality on utilitarian value → customer repatronage	-0.26^{*}	Supported	
H7: Moderation: FLE interaction quality on hedonic value → customer repatronage	NS	Not supported	

Note(s): $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; NS = not significant

2.5.2. Structural model - hypotheses testing

To evaluate the structural model and test the significance of the path coefficients, we ran a bootstrapping procedure with 5,000 samples (Hair *et al.*, 2011). The effect of the control variable related to the baseline service robot was insignificant on all endogenous variables ($p > 0.1$). The estimation results supported a positive effect (β = 0.65; p < 0.001; f^2 -= 0.73) of anthropomorphism on social presence, in support of H1. To test H2 and H3, we employed Rodrıguez-Entrena *et al.*'s (2018) approach to test the statistical differences between path coefficients. Using 95% basic bootstrap confidence intervals, we find support for H2, in that anthropomorphism has a statistically significant (CI [0.1190, 0.4748]) stronger effect on utilitarian value (β = 0.49; $p < 0.001$; $f^2 = 0.32$) than on hedonic value (β = 0.21; $p < 0.05$; $f^2 = 0.04$). Despite the larger positive effect size of social presence on the service robot's hedonic value (β = 0.45; $p < 0.001$; $f^2 = 0.18$) than its utilitarian value (β = 0.33; $p < 0.001$; $f^2 = 0.15$), this difference is not statistically significant as its confidence interval includes zero (CI [−0.3165, 0.0637]). Therefore, we cannot find support for H3. We did find support for H4, with a positive effect of a robot's utilitarian value on customer's repatronage intention (β = 0.23; $p < 0.05$; $f^2 = 0.05$). Surprisingly, the path between the robot's hedonic value and customer's repatronage intention was not significant and failed to provide support for H5 (β = 0.02; $p > 0.05$; $f^2 = 0.00$). Further, we find a negative moderation effect of human employees' interaction quality on the relationship between the service robot's utilitarian value and customer's repatronage intention (β = 0.26; $p < 0.05$; $f^2 = 0.04$), supporting H6. Finally, we report an insignificant moderation effect of human employees' interaction quality on the relationship between the service robot's hedonic value and customer's repatronage intention (β = 0.22; $p < 0.05$; $f^2 = 0.05$), thereby rejecting H7. **Figure 2.3** and **Table 2.4** summarize the results of the hypothesis testing.

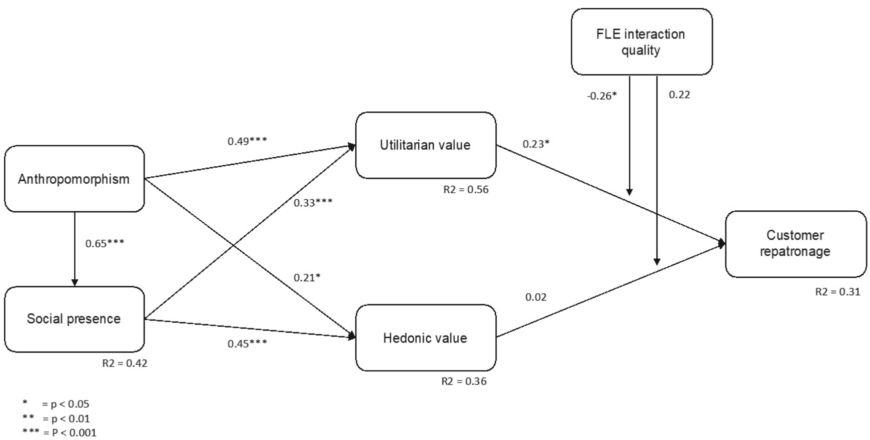

Figure 2.3. Structural model

To further expand on the moderation effects found in H6, **Figure 2.4** illustrates the relationships between the constructs. It displays the relationship between the service robot's utilitarian value, customer repatronage intentions and FLE interaction quality. The figure shows that in situations where the service robot's utilitarian value is at the mean and – especially – at lower levels, the FLE interaction quality does have a pronounced effect on customer repatronage intentions. In other words, FLE interaction quality can compensate for suboptimal levels of service robot utilitarian value, and FLEs can augment the service robots. However, in situations where service robot utilitarian value is high, there is not a pronounced relationship between the FLE interaction quality and customer repatronage intentions.

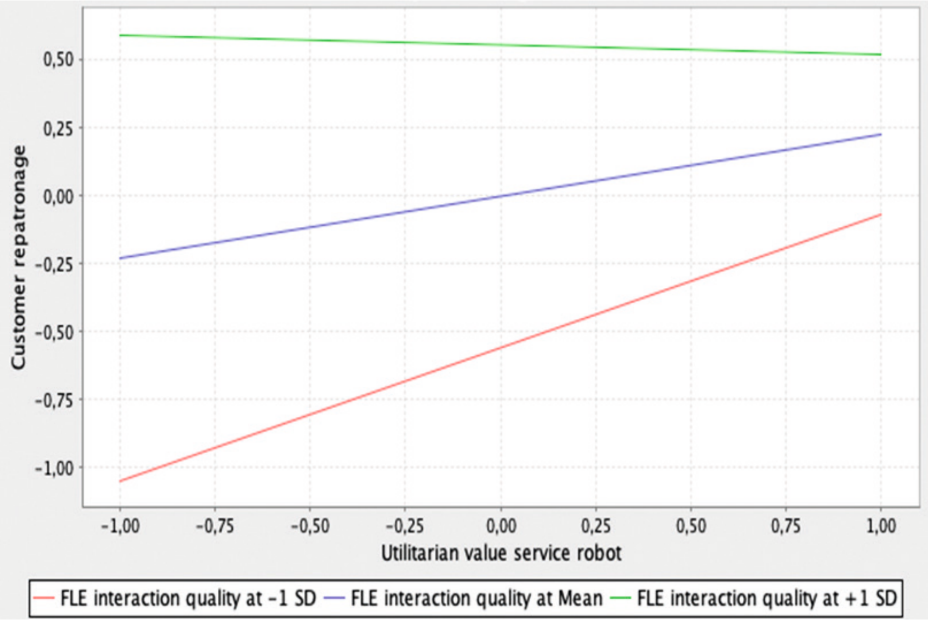

Figure 2.4. Simple slope lot representing moderation effect H6

2.6. STUDY 2 - METHOD

2.6.1. Scenario-based experimental design

To test the robustness of the findings related to hypotheses 4–7 from our field study, we conducted a scenario-based online experimental design. This setup allowed us to ensure more variation in FLE interaction quality and recruit a sufficiently large sample size during the 2020/2021 COVID-19 lockdowns.

2.6.2. Design, procedure and stimuli

We adopted a 2 (service robot utilitarian value: high, low) x 2 (service robot hedonic value: high, low) x 3 (FLE interaction quality: high, low, no interaction) between-subject design. For the high (low) service robot utilitarian value condition, the service robot took orders and served food and drinks in a highly (in)consistent and very (in)accurate manner. With respect to the service robots high (low) hedonic value, the service robot brought (did not bring) fun while serving drinks and foods by, for example, making jokes and was (not) entertaining by, for example, posing for pictures, making the interaction with the robot very (un)enjoyable. For high (low) FLE interaction quality, human employees were very (un)helpful, and how they interacted with the customers was excellent (horrible). For the FLE *control* condition of NO FLE, customers did not interact with any of the human employees and were only served by the robot.

At the start of the survey, participants were asked the following: "Imagine you visit a fast casual dining restaurant. The restaurant promises wordly food for small town prices. Customers typically come here for healthy dishes and fast service at an affordable price hence fast casual dining. In addition to the human employees that work at the restaurant, they recently also employed a new service robot, Akatar. Together with human employees, Akatar is serving the customers of the restaurant. A picture of the service robot Akatar in **Figure 2.1.** Thereafter, participants were randomly assigned to one of the experimental conditions. The exact information provided to the participants is shown in **Appendix 2.2** for each experimental scenario.

2.6.3. Sample and measures

Participants were recruited via Amazon Mechanical Turk (MTurk). We took several measures to ensure the quality of our data. First, we included an attention check (open ended question asking what the scenario was about) next to the standard manipulation checks. Second, we determined *a priori* that we only considered MTurkers from the US, as a native English-speaking country (Aguinis *et al.*, 2021). Third, we designed a short questionnaire (Hamby and Taylor, 2016). Fourth, we avoided using scales that only have the "end" points labeled (Goodman *et al.*, 2013). Fifth, only participants who passed the attention check and did not take less than 230 seconds or more than 10 minutes were retained as part of the final sample. Taking response times into consideration is a method to screen MTurk data for careless responding (Aguinis *et al.*, 2021). This resulted in a final sample of 361 usable responses (all from the US); M_{age} = 43.9, 51% male).

After exposure to the scenarios, our dependent variable customer repatronage was identical to our field study. In addition, we included prior experience with service robots, prior experience with fast casual dining restaurants and participant's gender and age as control variables. We used items from our field study constructs, which were based on existing measurement scales as manipulation checks. The manipulation check for utilitarian value was "To what extent would you rate the service robot Akatar as effective?". We used the statement "I have fun interacting with the robot" as a manipulation check for service robot hedonic value. As a manipulation check for FLE interaction quality, we included the item "Overall, I'd say the quality of my interaction with this restaurant's employees is excellent."

2.7. STUDY 2 - RESULTS

Table 2.5 shows an overview of the responses per experimental group. Construct validity and reliability tests were conducted and showed that individual item loadings, composite reliability and Cronbach's alpha values all exceed their minimum threshold of 0.7. Next to this, the AVE value exceeds 0.5, as indicated in **Tables 2.6 and 2.7**. The manipulation checks indicated a significant effect for all three manipulated factors: service robot utilitarian value (M_{low} = 3.73, SD = 2.16 vs. M_{high} = 5.73, SD = 1.20), $F(1,359)$ = 168.85, p < 0.001, service robot hedonic value (M_{low} = 2.98, SD = 1.86 vs. M_{high} = 5.28, SD = 1.46), $F(1,359)$ 5 25.08, p < 0.001 and FLE interaction quality (M_{low} = 3.10, SD = 1.88 vs. M_{high} = 5.46, SD = 1.24), $F(1,359)$ 5 39.00, p < 0.001.

Table 2.5. Number of responses for study 2 per experimental group

Factor	Category	*n*
Service robot utilitarian value	High	188
	Low	173
Service robot hedonic value	High	186
	Low	175
FLE interaction quality	High	117
	Low	126
	Control condition (no FLE interaction)	118

Table 2.6. Items and factor loadings for study 2

Construct (source) (Maxham III and Netemeyer, 2002)	**Items**		**Standardized loadings**
Customer Repatronage	1	I would expect to eat at this restaurant again in the next 6 months	0.977
	2	I am certain that I would be eating at this restaurant again in the next 6 months	0.976

Table 2.7. Mean, standard deviation and reliability estimates for study 2

Construct	**Mean**	**SD**	**AVE**	**CR**	α
Customer Repatronage	4.382	1.945	0.953	0.976	0.951

Note(s): The construct was measured on a seven-point interval scale; SD = standard deviation; AVE = average variance extracted; CR = composite reliability; α = Cronbach's alpha.

To verify the robustness of the findings of our field study related to hypotheses 4 and 6, we first analyzed a subset of our sample, leaving out the respondents who were in the control condition and did not experience any FLE interaction in their scenario. We conducted our analyses based on ordinary least squares regression using Hayes's PROCESS tool (custom model 1). We employed bootstrapped (N = 5,000) 95% bias-corrected confidence intervals. In addition, heteroscedasticity-consistent standard errors were computed as recommended by Hayes (2017). The effect of service robot utilitarian value on customer repatronage is positive and statistically significant (β =1.5476; $p < 0.001$; CI [0.9735, 2.1218]). Therefore, we provide additional evidence to support hypothesis 4. With respect to hypothesis 6, we found a negative moderation effect of FLE interaction quality on the relationship between service robot's utilitarian value and customer repatronage intentions (β = 1.0919; $p < 0.01$; CI [−1.8980, −0.2858]), providing additional evidence for hypothesis 6. Namely, in situations where the service robot's utilitarian value is low, FLE interaction quality has a pronounced effect on customer repatronage. Thus, FLEs can augment service robots by compensating suboptimal levels of service robot utilitarian value through FLE interaction quality. In contrast, if service robot utilitarian value is high, there is not a pronounced relationship between FLE interaction quality and customer repatronage. This effect is visualized in **Figure 2.5.** We controlled and found significant effects on customer repatronage for service robot hedonic value (β = 0.8622; $p < 0.001$; CI [0.4540, 1.2704]), participant's prior experience with service robots (β = 0.8394; p <0.01; CI [0.3042, 1.3745]) and fast casual dining (β = 0.5936; $p < 0.05$; CI [0.0773, 1.1100]), age (β = 0.0217 $p < 0.05$; CI [−0.0386, 0.0049]) and gender (β = 0.4362; $p < 0.01$; CI [0.0137, 0.8588]).

Employing the same procedure, we checked the robustness of the findings from our field study related to hypotheses 5 and 7. In contrast to the field study, the effect of service robot hedonic value on customer repatronage is positive and highly significant (β = 1.0690; $p < 0.001$; CI [0.4872, 1.6507]), providing new evidence to support hypothesis 5.We again find significant effects on customer repatronage for our control variables service robot utilitarian value (β = 1.0120; $p < 0.001$; CI [0.6014, 1.4226]), participant's prior experience with service robots (β = 0.8705; $p < 0.01$; CI [0.3312, 1.4098]) and fast casual dining (β = 0.5326; $p < 0.05$; CI [0.0231, 1.0422]), and age (β = 0.0203; $p < 0.001$; CI [−0.0374, 0.0032]). However, there is no evidence that the effect of service robot hedonic value on customer repatronage is moderated by FLE interaction quality. This insignificant effect is visualized for customer repatronage in **Figure 2.6**. As such, we fail to find support for hypothesis 7 in study 2, corroborating the result from our field study.

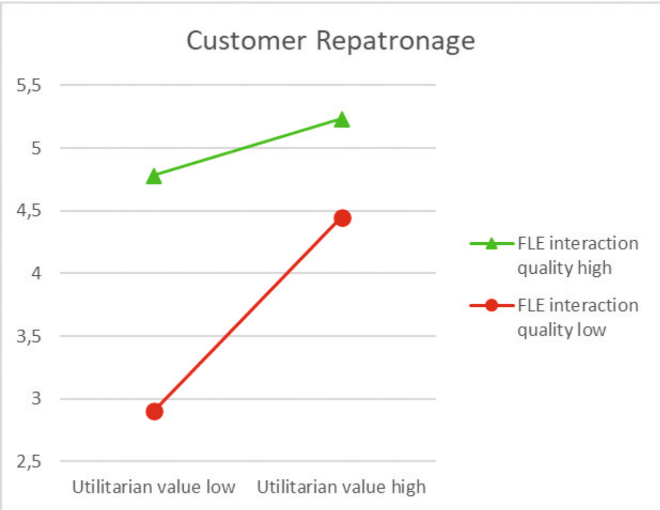

Figure 2.5. Visualized results of study 2 for H6

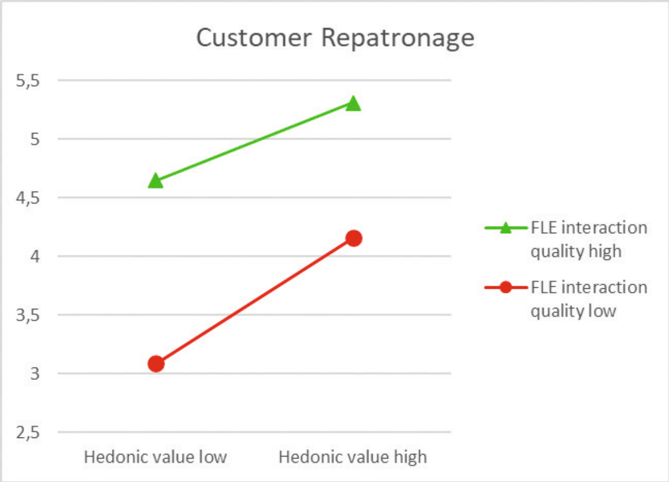

Figure 2.6. Visualized results of study 2 for H7

2.7.1. Additional moderation analyses including control condition

The service triad of technology-customer-FLE is central to study 1 and study 2. So far, the setup of our studies allowed us to investigate possible augmentation between FLE and service robot. To potentially isolate a substitution role in the scenario-based experimental design as well, we included a control condition in which customers were only served by the robot and not by human FLEs. We employed the same procedure as in hypotheses 6 and 7 (PROCESS custom model 1) but coded the three categories of our moderator FLE interaction quality (no interaction, low interaction quality and high interaction quality) using the indicator method (Hayes and Preacher, 2014).

Overall, we find that the relationship between the service robot's utilitarian value and customer repatronage intentions is moderated by the multicategorical moderator FLE interaction ($p < 0.05$). The effect of the service robot's utilitarian value on customer repatronage intentions is positive when there is no FLE interaction ($\beta = 1.3167$; $p < 0.001$; CI [0.6110, 2.0224]), similar to when FLE interaction quality is low ($\beta = 1.5298$; $p < 0.001$; CI [0.9554, 2.1042]). In contrast, the effect is not statistically significant if FLE interaction quality is high ($\beta = 0.4571$; $p > 0.1$; CI [−0.1053, 1.0195]). This indicates that service robots can potentially substitute customers' interaction with human FLEs if their utilitarian value is optimized. We find that the effect of the service robot's hedonic value on customer repatronage is not moderated by the multicategorical moderator FLE interaction ($p > 0.1$). The results of these additional analyses are depicted in **Figures 2.7 and 2.8**.

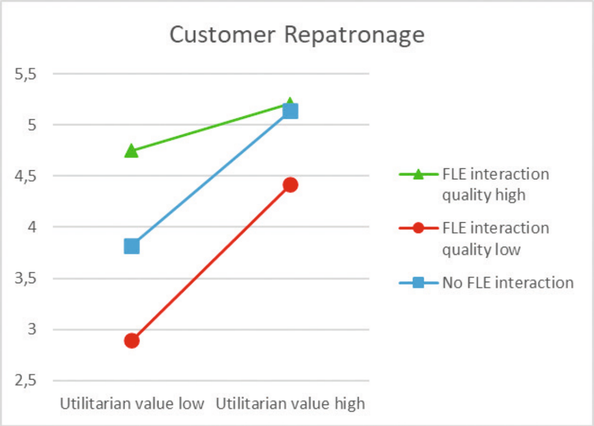

Figure 2.7. Additional analysis related to H6 including control condition

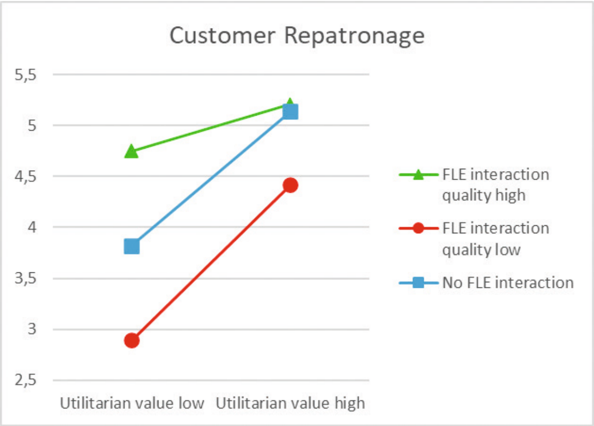

Figure 2.8. Additional analysis related to H7 including control condition

2.8. DISCUSSION

The triadic interdependencies between technology (e.g., service robots), human employees (e.g., FLE) and customers (e.g. customers in a restaurant) have been acknowledged in what Larivière *et al.* (2017) label Service Encounter 2.0. De Keyser *et al.* (2019) introduce conceptual archetypes to further capture different constellations of FLE and technology in the service frontline. Our field study and scenario-based experimental design in hospitality services in a fast casual dining restaurant supports the notion that the interplay between service robots and FLE contributes to customers' repatronage intentions.

As hypothesized, our empirical results demonstrate that when customers perceive an anthropomorphized service robot, they are also likely to perceive being with another social entity in the restaurant. Both anthropomorphism and social presence have a strong positive effect on utilitarian and hedonic value of the service robot. These results provide empirical support for the idea that humanoid service robots provide utility and gratification to customers in hospitality services (Ryan and Deci, 2001). In addition, our findings show that anthropomorphism has a stronger influence on utilitarian value compared to hedonic value. Anthropomorphism seen as a first-degree social response (Lee *et al.*, 2006), relating to the identification of fundamental human emotions and intentions, affects the provision of the core service (serving drinks and food) more than entertaining guests in the service triad.

Interestingly, only utilitarian value demonstrates a strong, significant, positive effect on customer repatronage in both studies. In the context of our hospitality services, customers seem to value the utilitarian aspects of the encounter (e.g., fast service, affordable prices and consistent/accurate interaction with the service robot). Our empirical findings based on service interactions with service robots in the triadic encounter is a refinement of an earlier study on the relationship between encounter pace and satisfaction, demonstrating that a higher encounter pace positively impacts satisfaction up to a certain tipping point (Noone *et al.*, 2009) as customers also value an enjoyable service encounter (hedonic value). Interestingly, the effect of hedonic value on customer repatronage is insignificant in the field study, yet significant in the scenario-based experimental design. This fascinating result can potentially be explained by the specific empirical context of the fast casual dining restaurant in the field experiment, in which the service robot possesses limited hedonic features. Namely, it communicates unilaterally and does not respond to customers. In the scenario-based experiment design, the service robot exhibits arguably higher hedonic characteristics as it makes jokes and poses for pictures. This finding extends existing retailing studies on the effect of hedonic value on customer repatronage (e.g., Atulkar and Kesari, 2017) to a triadic service encounter with service robots.

Our two studies provide support for our moderation hypothesis which posits that FLE interaction quality augments the effect of utilitarian value on customer repatronage. This finding illustrates the delicate interplay of actors within the customer-FLE-technology triad (De Keyser *et al.*, 2019; Larivière *et al.*, 2017). Namely, in situations where the utilitarian value of service robots is low, high FLE interaction quality leads to higher customer repatronage. In other words, given the triadic interdependencies, FLEs can augment a lower functional performance of service robots, and vice versa (Larivière *et al.*, 2017; Li *et al.*, 2021). To test for a replacement role within the service triad, we tested a scenario in which there is no FLE interaction, implying that the service robots take over the role of the FLEs. The results demonstrate that the same level of customer repatronage can be achieved without FLE interaction if the utilitarian value of the service robot is high. This suggests that in a fast casual dining restaurant, service robots with a high utilitarian value can make the interaction with FLEs redundant. This finding provides initial empirical evidence for a potential “substitution role” in Service Encounter 2.0, in which “technology promises to increase service encounter quality and efficiency, omitting inherent human staff variability” (Larivière *et al.*, 2017, p. 240; Li *et al.*, 2021), especially focusing on more consistency and accuracy (utilitarian value) in the service delivery by service robots in contrast to human variability.

2.8.1. Theoretical contributions

Our empirical findings from the field study of the triadic interactions between customers, service robots and FLEs in a fast casual dining restaurant provide three important theoretical insights. First, we provide empirical evidence for the interplay between different actors in the “customer-FLE-technology” triad (De Keyser *et al.*, 2019), resulting in favorable customer outcomes. In the modern-day Service Encounter 2.0, customer-company interactions that take place in service systems are comprised of interrelated technologies, human actors, physical/digital environments and company/customer processes (Lariviere *et al.*, 2017). In these settings, technology can both augment and substitute human FLEs (Marinova *et al.*, 2017; Li *et al.*, 2021). Companies that are able to find the right balance and roles for the different actors in the customer-FLE-technology triad will be able to attain a competitive advantage (Lariviere *et al.*, 2017). However, so far little is known in the service literature about how companies must strike a balance between the different actors and their roles. To the best of the authors’ knowledge, this is the first empirical study to provide insight into how perceived characteristics of different actors within the service triad (i.e., service robots and human employees) work in tandem to affect customer repatronage intentions. This has important implications for the current debate on the augmenting versus substituting role of frontline service technology within the service triad (Lariviere *et al.*, 2017; Li *et al.*, 2021; Ostrom *et al.*, 2021). We show that high-quality human FLE interactions in the service triad can augment the low utilitarian value of a service robot. In contrast, as the technology matures and service robots exhibit more utilitarian value to customers, the need for compensation through high-quality FLE interactions decreases and service robots can potentially substitute the human FLEs.

Second, the empirical findings advance service management literature by unraveling the relationship between anthropomorphism and social presence and their effect on perceived value. The study provides evidence for the fact that anthropomorphism – the humanlike emotions and intentions of the service robots – has a positive impact on the perceived social presence of the service robot. Extant research is inconclusive with respect to the effects of anthropomorphism. It posits that humanlike emotions and intentions can either inspire trust and bonding (Lu *et al.*, 2020; van Pinxteren *et al.*, 2019) or following the uncanny valley theory, customers may find a highly humanlike robot creepy and uncanny (Mori, 1970; Mori *et al.*, 2012), creating feelings of eeriness or a threat to (a customer's) human identity (Mende *et al.*, 2019). Our research shows that increasing anthropomorphism directly leads to social presence – a higher "sense of being with another" (Biocca *et al.*, 2003; Heeter, 1992). This is an important finding as it suggests that not only human FLEs (Wirtz *et al.*, 2018) but also service robots could be capable of building rapport with customers through their social presence. Moreover, we provide evidence for the important role that anthropomorphism and social presence play in hospitality services as utilitarian and hedonic value drivers. In particular, we conclude that anthropomorphism as *a first-degree social response* (Lee *et al.*, 2006) has a stronger effect on the utilitarian value of the service robot compared to its hedonic value. In other words, anthropomorphism impacts perceived quality of the core services provided such as serving food and drinks, stronger than perceived entertainment of customers.

Third, our studies provide strong empirical evidence for utilitarian value of service robots as a driver of customer repatronage to fast casual dining restaurants. Existing research on robots in hospitality services (see Table 1) is either conceptual in nature or uses laboratory experiments with hypothetical scenarios. Lu *et al.* (2020) indicate that field study research is needed to actually understand the extent to which and how service robots influence customers' outcome variables. Our field study as well as our scenario-based experimental design indicates that in the context of fast casual dining restaurants, service robot's utilitarian value has a pronounced effect on customer repatronage. Understanding the important role of service robot's utilitarian value in fast casual dining restaurants adds to our theoretical knowledge of how service robots can influence customer repatronage in hospitality.

2.8.2. Managerial implications

This study provides service managers of triadic service encounters with valuable insights on the implementation of service robots in frontline services and in particular, in restaurants. First, we find evidence that in hospitality services which used to be a "game of people" (Bowen, 2016), FLEs no longer always need to take an active role in the service encounter as there is a potential for service robots to substitute FLEs. Namely, we find that in fast casual dining restaurants, service robots that achieve high levels of functional performance (i.e., utilitarian value) can replace the need for customers to engage in high-quality interactions with FLEs. From the restaurant owner's perspective, implementing service robots can lead to cost reductions and productivity gains (Wirtz and Zeithaml, 2018). Especially in the social distancing era of the COVID-19 pandemic, service robots could contribute to minimizing the risk of spreading the virus. Also, services robots can be a solution to ensuring sufficient capacity to deliver consistent service in times of high staff shortages.

Second, our empirical findings have implications for service settings in which service robots should not substitute but rather be augmented by FLEs. We find that FLEs can compensate for lower levels of functional performance (i.e., utilitarian value) of service robots by engaging in high-quality interaction with customers. By demonstrating a high willingness to help and having excellent interactions with customers, FLEs can augment service robots that exhibit lower levels of utility to achieve customer repatronage. This advocates the joint service delivery by FLE – service robot teams in situations where service robot technology is not fully optimized. In this sense, technology and FLE can be used in tandem to provide a better service outcome (Froehle and Roth, 2004; Li *et al.*, 2021).

Third, we provide essential insights for robot engineers and designers, gathered from a real-life setting (Mende *et al.*, 2019) on the human likeness design parameter of service robots. The findings from our field study show that the more service robots in restaurants evoke the perception of having thoughts and emotions, the higher customers evaluate the robots' utilitarian and hedonic value. This indicates that service robots should be designed in a way to display social presence by having the ability to have thoughts and convey emotions in order to create customer value.

Fourth, our results have implications for policy makers as well. Recently, the Future of Jobs report published by the World Economic Forum (2020) articulated that the surge in digital technologies and automation largely transforms tasks, jobs, and skills within the next five years. In line with these developments, Lariviere *et al.* (2017) emphasized the importance of role readiness for employees to acclimate in the new service environment. This demands a completely new set of skills and a proactive attitude from the public sector to support reskilling and upskilling for employees (Huang and Rust, 2020; World Economic Forum, 2020). This study shows that the jobs of FLEs in hospitality will be subject to change, such that they in some cases will be substituted and in other cases augmented by service robots. Policy makers should prepare the workforce in hospitality for this change by providing FLEs with the opportunity to reskill (in case of job substitution) or upskill (in case of job augmentation). We advocate for training specific collaborative skills on how to work with a service robot in a team.

2.8.3. Limitations and future research

This research offers several avenues for future research. First, the empirical context of our field study entails a European, fast casual dining restaurant. Next to this, the sample is skewed since most of the respondents were female (70.8%), between 18 and 34 years old (81.5%), repeat customers (69.4%) and visiting the restaurant with friends (62%). Moreover, we carried out our research during the 2020/2021 COVID-19 pandemic. This warrants caution regarding the generalizability of our findings. Future studies should shed more light on this by conducting similar investigations across different cultural settings, types of restaurants and beyond the pandemic. In particular, it would be interesting to obtain insight into whether service robot's utilitarian and hedonic value play a more or less pronounced role in hospitality settings other than fast casual dining restaurants, and how this potentially affects the interplay between the different actors of the service triad.

Second, the service robots that were employed by the fast casual dining restaurant in our field study were endowed with limited hedonic characteristics. Namely, they communicated unilaterally and could not respond to customers, make jokes, or pose for pictures. This may explain the lack of a significant relationship between the service robots' hedonic value and customer repatronage, contrary to the findings of our scenario-based experiment. Contemporary service scholars postulate that service robots will be able to deliver cognitively complex service tasks and low emotional service tasks (Lu *et al.*, 2020; Paluch and Wirtz, 2020; Wirtz *et al.*, 2018). Building on these insights, we encourage future service scholars to develop field studies to further disentangle the service triad and the link between service robot hedonic value, customer repatronage intentions and FLE interaction quality. Another interesting avenue for future research is the analysis of actual customer behavior demonstrating perceived hedonic value, such as taking a picture or video of the service robot or dancing with the robot, instead of mere customer perceptions.

Third, in our field study, we base our findings on a cross-sectional sample of customers in a triadic service encounter, obtained in the early stages of service robot implementation. This opens up the opportunity for further research to take a longitudinal perspective on the effects of service robot implementation in hospitality as it would be valuable to understand the extent to which our findings hold for revisiting customers over time.

Fourth, future research could further expand our knowledge on factors – beyond FLE interaction quality – that affect the relationship between service robot's utilitarian and hedonic value and customer outcomes. Interesting research questions could be: what is the impact of the utilitarian and hedonic value of the FLE, or to what extent do customers' prior experiences with the robot or the type of party (friends versus family versus business relations) play a role in the interactions with service robots and the effects it has on customer outcomes?

Fifth, it is worthwhile to study how augmentation or substitution by service robots in the service triad for certain tasks affects the employee experience. Do employees feel empowered by their robotic counterpart or rather threatened to become obsolete? While the customer experience has received major academic interest, so far research in the domain of the employee experience has been scarce (Lariviere *et al.*, 2017).

Lastly, we encourage researchers to further expand the service triad by investigating how third parties – such as other employees or other customers – are influenced by and influence the interplay between customers and a team of service robots and frontline employees. Researchers increasingly consider the role of third parties who interact with customers and/ or service providers (Abboud *et al.*, 2021), and future research can explore how employees fulfill the third-party roles of bystander, connector, endorser, balancer, or partner role in indirect interactions (Abboud *et al.*, 2021). This research direction builds on Bowen's (2016) call for further investigation of employee roles in an evolving service context characterized by growing technologies augmenting employees. In this context, future research can investigate whether and how frontline employees can create value by adopting a third-party role when service robots are directly interacting with customers.

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CHAPTER 3

DO WE THINK AND FEEL ALIKE? FIELD EVIDENCE ON DEVELOPING A SHARED REALITY WHEN DEALING WITH SERVICE ROBOTS.

In the case of this chapter:
Steins, M., Becker, M., Odekerken-Schröder, G., Mathmann, F., Mahr, D., & Russell-Bennett, R. (2024). Do we think and feel alike? Field evidence on developing a shared reality when dealing with service robots. *Journal of Business Research*, 180, 114729.

3.1. INTRODUCTION

Wally the robot butler is pretty awesome, he frightened my husband at first, but after he got used to it, he ended up looking for reasons to have Wally deliver something to our room.
—Online hotel review

Fueled by advances in artificial intelligence (AI) and labor shortages, service robots appear in diverse service industries (Haenlein & Kaplan, 2021)—serving in restaurants, assisting in supermarkets, or delivering hotel room service (Bertacchini *et al.*, 2017; Fuentes-Moraleda *et al.*, 2020; Odekerken-Schröder *et al.*, 2022). Noting robots' substantial impact on customer experiences (Wirtz *et al.*, 2018), various researchers have evaluated robot-enabled services (Becker *et al.*, 2023; Mende *et al.*, 2019), though mostly in simulated online experiments (De Keyser & Kunz, 2022). The literature features few observations of real-life human–robot interaction (HRI) at service frontlines and little consideration for the complex social context in which they take place. Yet HRI rarely takes place in isolated dyads of a customer and a service provider (De Keyser *et al.*, 2019). Customers often use services together with other group members, such as friends, family members, or colleagues, creating what we refer to as collective service experiences. In these settings, appraisal theory is especially pertinent, as it not only acknowledges individual coping resources but also recognizes the supportive presence of other group members, offering directly accessible shared coping resources (Lazarus & Folkman, 1984). Consider the opening quote from a customer review; while in a spouse's presence, the husband initially had a negative appraisal of the service robot (e.g., fear) but then coped with the situation (e.g., getting used to it) and even repurchased the room service to interact with the robot. Such appraisal and coping responses are predicted by appraisal theory (Lazarus & Folkman, 1984), which describes how people assess, interpret, and respond to difficult or challenging situations. In turn, some customer appraisals of HRI might be negative (e.g., as a threat), but others likely are positive (e.g., as a challenge). Based on this initial appraisal, customers adopt distinct coping strategies (Lazarus & Folkman, 1984), such as problem-focused coping (e.g., actively dealing with the service robot), emotion-focused coping (e.g., expressing feelings about dealing with the service robot), or social support seeking (e.g., reaching out to others for assistance or empathy in dealing with the service robot; Duhachek & Iacobucci, 2005; Folkman *et al.*, 1986). While research on service robots has explored user perceptions (e.g., De Keyser & Kunz, 2022), only Paluch *et al.* (2022) have specifically applied appraisal theory to HRI, focusing on employee reactions. Consequently, it remains less understood how customers, as opposed to employees, appraise and cope with service robots.

Especially during collective service experiences, customers influence each other's perceptions and reactions, shaping a socially constructed reality (Carù & Cova, 2015). For example, talking about the experience or asking for help, affects how individuals perceive HRI. However, as Carù and Cova (2015, p. 279) caution, "Collective experiences are not central to service knowledge." To address this gap, we explore how customers form opinions about HRI within collective service experiences, hypothesizing that customers who are coping with frontline service robots collectively—and in each other's presence—foster a joint understanding of the event, also known as a shared reality (Rossignac-Milon *et al.*, 2021). Research on HRI has mainly observed isolated dyads of one customer and service provider (Odekerken-Schröder *et al.*, 2022), overlooking the impact of HRI within groups of customers on outcomes like switching intention and word-of-mouth. Examining these outcomes is crucial, as they entail long-term consequences, beyond the purchase stage and are vital for long-term business success (Lemon & Verhoef, 2016). This research addresses the current gap by investigating post-purchase effects of collective service experiences involving service robots.

Our study investigates post-purchase outcomes, specifically switching intention—a customer's likelihood to switch providers (Keaveney, 1995)—and relational service well-being, which reflects the positive relationship with a service provider stemming from personal experiences (Falter & Hadwich, 2020). This research aids in understanding the broader implications of HRI in customers' collective service experiences.

Therefore, to determine (1) how customers appraise and cope with HRI during collective service experiences, (2) the role of a shared reality pertaining to service robots' encounters, and (3) the impact of appraisal, coping, and shared reality formation processes on post-purchase customer outcomes, we investigate HRI during collective service experiences with a qualitative field study involving 1107 online hotel reviews (Study 1). Our primary aim in Study 1 is to gain insights into these dynamics in real-world settings. Following the approach by Pitardi *et al.* (2022), we combine the findings from Study 1 with our conceptual background to develop a research model and hypotheses, which we empirically test in a field study at a European fast-casual restaurant, involving 310 participants (Study 2).

The findings contribute to the literature on frontline service robots in four significant ways. First, our study enhances understanding of service robots by demonstrating that customers use personal (e.g., self-efficacy) and shared (e.g., collaborative actions) resources to cope with HRI at the service frontline. While existing appraisal and coping studies usually refer to negative consumption events and their emotional consequences, our study broadens the scope of appraisal theory to novel and potentially positive encounters, exemplified by HRI at the service frontline. This expansion of the theoretical framework highlights the versatility of appraisal theory in encompassing a broader range of customer experiences, including interactions with new technology (Ciuchita *et al.*, 2019). Furthermore, by delving into frontline interactions between customers and service robots, our study addresses recent calls for applying appraisal theory to explain how HRI unfolds at the service encounter (Paluch *et al.* 2022).

Second, our field study identifies two unintended post-purchase consequences of introducing HRI at the service frontline. These consequences are considered 'unintended' because service robots are not deployed to evoke feelings of threat or discomfort. Yet, customers who perceive HRI as threatening display lower levels of relational service well-being, experiencing lower levels of trust, fairness and being taken seriously. Alongside, these customers are more likely to switch to alternative service providers, indicating decreased loyalty. Therefore, although service robots are deployed to enhance customer experiences (Wirtz *et al.*, 2018), our study highlights potential adverse and unintended post-purchase outcomes of HRI at the frontline.

Third, our study provides evidence for the emergence of a shared reality, as described by Rossignac-Milon *et al.* (2021), regarding service robots within the context of HRI during collective service experiences. This contribution is significant as it operationalizes how collective experiences shape customer perceptions and attitudes towards service robots, thereby enriching the theoretical framework of shared reality in the context of customer interactions with service frontline technology. Our findings underscore the need for both scholars and practitioners to recognize the significance of the collective context in which HRI in service settings occurs. Specifically, the study stresses the importance of a shared understanding of the robot and the role of appraisal and coping processes in shaping these perceptions.

Fourth, our research advances service robot literature by exploring the social context surrounding HRI at real-life service frontlines. While current literature has been mainly restricted to controlled or conceptual studies, our work bridges this gap, emphasizing the collective nature of real-life experiences often overlooked in lab settings (Lu *et al.*, 2020). Echoing Castelo *et al.*'s (2023, p.2) sentiment that "the use of new technologies does not occur in a vacuum"; we complement current literature by investigating HRI within collective service experiences, where customers influence one another's thoughts and behaviors (Carù & Cova, 2015). Real-life service contexts, as highlighted by Mende *et al.* (2019), provide a richer understanding of HRI. Our study is among the first to explore shared reality perceptions about service robots among groups of customers, acknowledging the social context of collective service experiences where HRI frequently takes place. By conducting field studies, we aim to capture difficult-to-replicate contextual and social dynamics that drive post-purchase customer outcomes beyond mere robot perception.

3.2. CONCEPTUAL BACKGROUND

3.2.1. Human–robot interaction

Service robots, defined as "system-based autonomous and adaptable interfaces that interact, communicate and deliver service to an organization's customers'' (Wirtz *et al.*, 2018, p. 909), are increasingly permeating various service settings (Huang & Rust, 2021). Their growing presence, especially at service frontlines (Hoffman & Novak, 2018; Ostrom *et al.*, 2015) amplifies the significance of technology-mediated customer contacts, such as HRI (Froehle & Roth, 2004). With more and more "technology infusion", van Doorn *et al.* (2017) predict considerable changes to the nature of the interactions of customers and service organizations, influencing both frontline employees (FLEs; Paluch *et al.*, 2022; Phillips *et al.*, 2023) and customers (Mende *et al.*, 2019; Pitardi *et al.*, 2022). However, a critical gap persists in understanding customer perceptions, evaluative outcomes (Wu *et al.*, 2021), and post-purchase consequences, necessitating our investigation into the impact of robot-assisted services.

3.2.2. Dealing with HRI

Appraisal theory (Lazarus & Folkman, 1984) suggests that certain situations and events create disequilibria that people have to regulate. Consequently, research has applied this theory to anticipate the effects of innovative e-services on customer experiences (Ciuchita *et al.*, 2019). Related to HRI specifically, Paluch *et al.* (2022) demonstrate that interactions involving employees can be modeled as multistage processes of appraisal and coping. During primary appraisals, people evaluate what is at stake, which leads them to anticipate irrelevant, positive, and pleasant, or negative and stressful outcomes (Fadel & Brown, 2010; Lazarus & Folkman, 1984). Coping involves efforts to find ways to manage these outcomes (Lazarus, 1991).

Appraisal of HRI. In HRI, customers might appraise the encounter as a threat or a challenge (Lazarus & Folkman, 1984), following their perceptions (Fadel & Brown, 2010). Threat appraisals are typically negative, triggered by excessive demands or losses, while challenge appraisals are positive, recognizing opportunities to make gains (Duhachek, 2008). Despite acknowledging that service robots alter customer interaction dynamics (De Keyser *et al.*, 2019; Larivière *et al.*, 2017), understanding of how these robots influence customer appraisals and subsequent reactions remains limited. Negative appraisals may result from feelings of intimidation, or embarrassment from unfamiliarity, potentially leading to perceived harm. Conversely, challenge appraisals of HRI might lead to customers' excitement to learn or experience something new (Lazarus & Folkman, 1984).

Coping with HRI. Based on their appraisals, customers choose coping strategies (Lazarus, 1991; Lazarus & Folkman, 1984), involving cognitive, emotional, and behavioral efforts to handle challenges or threats (Duhachek, 2008; Han *et al.*, 2016). In HRI, coping helps customers interact effectively with a service robot, providing situational means to navigate this scenario (Duhachek, 2008). Bagozzi *et al.* (2022) hint at HRI's emotional complexity yet how customers cope with these emotions and their influence on engagement with service robots remains unexplored.

Coping strategies can be categorized broadly as emotion-focused or problem-focused (Duhachek, 2008; Lazarus & Folkman, 1984). The former involves alleviating emotional distress by managing stress and anxiety (e.g., expressing feelings about dealing with the service robot), while the latter entails taking action in addressing the originating stressor (e.g., actively dealing with the service robot). Despite their fundamental importance, a simple dichotomy between managing emotional responses and addressing the root of the stressor may not fully capture the wide array of strategies customers use, especially in collective service experiences where the experience is intentionally shared among customers. We propose social support seeking (e.g., reaching out to others for assistance or empathy in dealing with the service robot) as a third coping strategy, arising from the need for help during stressful encounters (Folkman *et al.*, 1986). It emerges as a distinct strategy due to its explicit outward-oriented, help-seeking component (Folkman & Lazarus, 1985), where during collective service experiences, other customers can form an instantly accessible support network to address HRI.

3.2.3. Social contexts in collective service experiences

Customer experience literature identifies the social context as an important component of customer experiences (Bolton *et al.*, 2018) and as a situationally available resource, based on social relationships (De Keyser *et al.*, 2020; Verhoef *et al.*, 2009). Customers rarely act in isolation; instead, they interact with their surroundings, shaping their perceptions (De Keyser *et al.*, 2020). During service experiences, they encounter others, such as FLEs and fellow customers, who influence the social context (Abboud *et al.*, 2020; Larivière *et al.*, 2017). Our research focuses on HRI with frontline service robots among collectives intentionally engaging and sharing in the service together as a group. Consequently, the social context encompasses other group members, such as family, friends, or colleagues. During collective service experiences, these others provide directly accessible resources, also referred to as 'shared resources in our research'. In an empirical study that acknowledges the importance of the social context, Pitardi *et al.* (2022) both cite the social complexity that underlies many frontline service encounters. Odekerken-Schröder *et al.* (2022) suggest exploring how other customers' perceptions affect interactions between a focal customer and a service robot, including their influences on the customer experience and post-purchase outcomes. Building on these studies, we seek to determine how HRI-related appraisal and coping processes during collective service experiences might produce a shared reality of service robots.

Shared reality. Shared reality refers to "the perceived commonality of inner states (e.g., feelings, beliefs or concerns) with another person about a target referent (e.g., an event, an object, or a third person)" (Rossignac-Milon *et al.*, 2021, p. 2). In our study, the target referent is the service robot. Shared realities inform human connections and sense making, providing affirmation (Hardin & Higgins, 1996). Individuals need to experience shared realities to satisfy relational needs (e.g., feeling connected to and affiliated with others), and epistemic needs (e.g., sensemaking) to validate their experiences (Rossignac-Milon & Higgins, 2018) and understanding of the world (Echterhoff *et al.*, 2009; Hardin & Higgins, 1996). Making shared sense of a target referent (e.g., service robot) with others creates a reliable, objective sense of reality (Hardin & Higgins, 1996), which in turn enhances a sense of predictability and self-efficacy (Echterhoff *et al.*, 2009). Moreover, feeling connected to others is linked to emotional well-being, security, and self-esteem, especially in anxiety-inducing situations (Echterhoff *et al.*, 2009), such as when interacting with novel service robots during shared service experiences.

3.2.4. Post-purchase outcomes

We examine post-purchase outcomes after collective service experiences with service robots, noting the lack of consideration in the service domain. Odekerken-Schröder *et al.* (2022) offer a notable exception, investigating how customers' value perceptions of robots influence repatronage intention, or the likelihood to repurchase or continue using the service, as opposed to switching intention, which indicates a preference to change service providers (Keaveney, 1995). These outcomes have not yet been researched after collective service experiences. Recognizing their long-term implications for customer lifetime value (Lemon & Verhoef, 2016), we investigate two critical post-purchase service outcomes that are likely influenced by HRI at the service frontline: 1) relational service well-being, which includes trust towards the service provider and feelings of being treated fairly and taken seriously (Falter and Hadwich, 2020); and 2) switching intention, which indicates a readiness to switch to another service provider (Keaveney, 1995). Noting that the use of service technologies, including robots, influences customer judgements about the service provider (Belanche *et al.*, 2021a; Castelo *et al.*, 2023), makes investigating these outcomes crucial for understanding HRI's impact on post-purchase attitudes and behaviors.

Relational service well-being. It is commonly acknowledged that service providers should not only focus on business outcomes, but also have a keen eye on customer well-being, as emphasized by the Transformative Service Research stream (Ostrom *et al.* 2015). In psychological research, two main well-being traditions can be identified: eudaimonic and hedonic well-being, often referring to mental health (Ryan and Deci, 2001). However, trying to measure the overall well-being of customers in a subordinate area of life such as dining or other specific service contexts seems unrealistic. Therefore, the current study explores relational service well-being, one of the dimensions of Falter and Hadwich's (2020) construct of customer service well-being that acknowledges the importance of frontline interactions. Following their conceptualization, we define relational service well-being as *the positive relationship with a service provider stemming from personal experiences.* Specifically, it encompasses trust towards the service provider, feelings of being treated fairly and taken seriously. Validating relational service well-being in the context of HRI at the frontline is particularly relevant for two reasons. First, while service robots excel in complex cognitive tasks, their capacity for emotional and social engagement is notably constrained (Becker *et al.*, 2022). Consequently, it is pertinent to assess how HRI affects perceptions of trust, fair treatment, and evaluations of being taken seriously. Second, the deployment of service robots might change the nature of customer-FLE interactions (Odekerken *et al.*, 2022; Reis *et al.*, 2020), also referred to as the 'intrusion challenge' (Phillips *et al.*, 2023). In line with such an intrusion challenge, Belanche *et al.* (2021a) and Capello *et al.* (2023) suggest that integrating service robots fundamentally alters customers' perceptions of their relationship with service providers and impacts perceived commitment to customer well-being. This extends beyond immediate interactions to affect the overall relationship, emphasizing the need to understand how HRI influences relational service well-being.

Switching intention. Losing customers undermines market share and profitability (Keaveney, 1995), and acquiring customers is costlier than retaining them (Liu *et al.*, 2011). Therefore, service providers should pursue strong retention (Keaveney, 1995; Liu *et al.*, 2011), though HRI might hinder this by preventing service providers from building personal, lasting relationships with customers (Rafaeli *et al.*, 2017). However, Odekerken-Schröder *et al.* (2022) found that perceived value of service robots increases repatronage intention, and Belanche *et al.* (2021b) outlined robot humanness positively affects loyalty intentions. To contribute to this ongoing discussion, the current study focuses on the impact of HRI-related appraisals and coping, as well as shared reality about service robots during collective service experiences, on customers' switching intention.

3.3. STUDY 1: QUALITATIVE ANALYSIS OF ONLINE CUSTOMER REVIEWS

The purpose of Study 1 is threefold. First, it seeks to understand what appraisals customers hold towards service robots, how they cope with these appraisals, and in what contexts they do so. Similarly, Study 1 also seeks to gain an understanding of what post-purchase outcomes are impacted by these processes. Second, Study 1 seeks to establish relative frequency of these four core concepts to gain insights into their relative (pre)relevance. Third and most importantly, Study 1 provides insights based upon real-life customer experiences for developing our hypotheses, which are tested in Study 2.

3.3.1. Methodology

The study relies on 1107 online reviews (ORs), posted by hotel guests between November 2014 and September 2021 to five major online review websites that directly mention services delivered by a service robot. All reviews refer to eight hotels, located in the same U.S. state, which all employ the same service robot for delivering hotel amenities to guests' rooms (see **Figure 3.1**). We employed a combination of the critical incident technique (CIT; Flanagan, 1954) and qualitative content analysis to analyze these qualitative posts treating each mention of a robot as a critical incident that could provide relevant insights into the constructs of interest. Therefore, we first extracted the relevant pieces of text that related to the robot.

Afterwards, we conducted a qualitative content analysis in line with best practices outlined by Stemler (2001). First, the first two authors developed an a priori coding scheme for the study's core constructs of interest, using each construct's conceptualization in the literature to define an initial set of codes in the form of words and phrases. This initial coding scheme was then further refined based on the actual content analysis (Stemler, 2001). Besides switching intention and relational service well-being, we also included word-of-mouth and repurchase intention in our analysis. The coding scheme is shown in **Figure 3.2**, with further details provided in **Appendix 3.1**.

Based on this coding scheme, two authors analyzed the content of every review to determine whether a specific construct was present. This process was done independently and in case of differences, these were discussed until convergence was achieved (Stemler, 2001). Finally, the authors extracted quotes that represented the core constructs particularly well and counted the occurrence of each to get an estimate of their relative relevance. The constructs and illustrative quotes from ORs are presented in **Table 3.1**.

Figure 3.1. Robot in Study 1

3.3.2. Results

The first insight we gain from our qualitative analysis is that about 66% of ORs describe collective service experiences in which customers intentionally experienced the service together (e.g., as part of a family or friend group). Moreover, we can often see that during these collective service experiences, customers form a shared reality (20%).

Moreover, while not all reviews describe appraisals and coping, we see that a vast majority of reviews describe challenge (i.e., positive) appraisals (77%), such as excitement or potential gain (see OR#2). Threat (i.e., negative) appraisals are only described by a few customers. Nevertheless, even online, where people might be hesitant to openly discuss their fears (Wakefield & Wakefield, 2018), threat appraisals can still be identified (4%), such as in OR #3.

Themes of Interest	Constructs of Interest	Codes
Appraisal	**Challenge appraisal** (Lazarus & Folkman, 1984)	• **Positive perception of robot** (e.g., cool, cute, awesome, friendly, fun) • **Excitement** (e.g., wow, amazing, highlight, favorite, wonderful) • **Affection** (e.g., love, adore)
	Threat appraisal (Lazarus & Folkman, 1984)	• **Negative perceptions of robot** (e.g., weird, disconcerting, inconvenient) • **Fear** (e.g., frightened, shocked, freaked out) • **Disappointment** (e.g., disappointed, sad)
Coping	**Problem-focused coping** (Lazarus & Folkman, 1984)	• **Taking active action** (e.g., used, tried, called, ordered, touched) • **Taking passive action** (e.g., observed, watched, looked, followed)
	Emotion-focused coping (Lazarus & Folkman, 1984)	• **Expression of emotions** (e.g., I loved, I was scared, I was shocked) • **Reinterpretation of the situation** (e.g., at first, in the end)
	Social support seeking (Folkman et al., 1986)	• **Fellow customers support** (e.g., talked with other guests about the robot, asked the neighbors) • **Staff support** (e.g., asked the staff, notified the staff, staff showed / explained)
Shared reality	**Shared reality** (Rossignac-Milon et al., 2021)	• **Speaking for others** (e.g., we loved, our experience, it amazed us)
Post-purchase outcomes	**Relational service well-being** (Falter & Hadwich, 2020)	• **Fair treatment** (e.g., feeling fairly treated, honest, sincere, respectful) • **Taken seriously** (e.g., feeling professionally treated, helpful, considerate, good service) • **Trust** (e.g., trust, feeling secure/safe, reliable)
	Switching intentions (Keaveney, 1995)	• **Avoiding the hotel** (e.g., will avoid, will not return, never again, not ready)
	Repurchase (Hellier et al., 2003)	• **Reordering deliveries** (e.g., ordered more, called down again) • **Rebooking hotel stay** (e.g., brought me back, I will come again)
	Word-of-mouth (Babin et al., 2005)	• **Sharing** (e.g., talk about, told) • **Recommending** (e.g., you must check-out / try, I recommend)

Figure 3.2. Coding Scheme Study 1

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Table 3.1. Key constructs and illustrative quotes

Construct (% of all reviews)	Illustrative quotes from online reviews (ORs)
Appraisal	
Challenge appraisal (77%)	"I called downstairs to request toilet paper to my surprise a robot was at my door within minutes...totally cool she also called my room to let me know she was at door. I'm still in amazement of this unique service." [OR #1] "Strangely enough, there was no toothpaste/toothbrush in the room, so I called up room service and amazingly enough, Hannah the robot came to the door and delivered me the toothbrush. Really great little gimmick." [OR #2]
Threat appraisal (4%)	"I was impressed with the Robot, even though It kind of freaked me out when i opened the door. Didn't expect that." [OR #3] "The only minor disappointment was the fact that Winnie the robot butler suffered from mechanical troubles attempting to deliver items to our room." [OR #4]
Coping	
Problem-focused coping (4%)	"We LOVED Wally and finally rang down to ask for him to deliver something!" [OR #5] "when Winnie came off the elevator and down to our room, it went past us to another room. I kept thinking that it must have had multiple orders, but when I realized it wasn't coming back to our room, I finally had to go to the perplexed people and ask if that was their order, or mine. They hadn't ordered anything, so took my melty ice cream and had to tell Winnie it was done and to head back to the docking station." [OR #6]
Emotion-focused coping (28%)	"There's also a robot that delivers candy and items from the store which was a little bit weird but pretty convenient." [OR #7] "The only thing that scared me at first was the Butler robot , but I got used to it." [OR #8] "Love the robot that brings towels, wash cloths, etc. to your room." [OR #9]
Social support seeking (1%)	"The front desk staff, especially John, was super friendly and helpful. He really went the extra mile to make sure I felt welcome. He even gave me a demonstration of the "robot" butlers that bring items to the rooms." [OR #10] "I would have loved to have had Rose' explained to me when we arrived. I totally needed her services, (went to bed hungry) the first night!" [OR #11]

Table 3.1. Continued

Construct (% of all reviews)	Illustrative quotes from online reviews (ORs)
Shared reality (20%)	"Our family got the biggest kick out of Rose the Robot. It was like R2D2 was delivering things to our door. We loved it!" [OR #12] "We love Wally! He is the other main reason we always return. My children light up when Wally the Robot butler makes a delivery to our room." [OR #13]
Post-purchase Outcomes	
Relational service well-being (1%)	"Omg, Rosie the butter robot made my stay!! She is so friendly and professional!! I wish I had a Rosie at home, I'm going to miss her" [OR #14] "Yes... I guess two stars for the robot because IT's service was faster than the actual humans in this hotel. We asked for a towel last night and a human lady took half an hour to come by. We called this morning for toilet tissue and the robot was at our door in 10 minutes!" [OR #15]
Switching intentions (1%)	"The one that freaked me out (wait till you see it in action) is the robot they have that actually delivers room items to your door. Never used it, but wait until you come around the hall corner and see this thing or even worse it gets in the elevator with you. I guess I'm not ready for Star Wars yet." [OR #16]
Repurchase intentions (2%)	"She is a robot who makes deliveries to the room (it's a great marketing tool because we never would have had so many over priced snacks from the market if not for Rose bringing them up ha ha)." [OR #17] Loved it loved Wally thought it was coolest invention ever. That's what brought me back. [OR #18]
Word-of-mouth (5%)	"I was so amazed I had to show my friends so I ordered about $30s in drinks from Starbucks to see if he was able to carry all that in his little compartment and he did!!" [OR #19]

Our analysis further reveals that customers engaged in three main coping strategies. By far being the most frequent (28%), many customers engaged in emotion-focused coping. For example, OR #8 describes how the guest accepted the situation or OR#7 shows how the customer changed their perspective on it. Many ORs also appear to provide customers with a medium through which they can let out their emotions (e.g., OR#9). Also problem-focused coping is visible in the ORs. For example, guests describe how they acted upon their challenge appraisal (e.g., OR#5). Yet, most of the analyzed reviews focus on perceptions and feelings rather than actions, with problem-focused coping (4%) being considerably less frequent than emotion-focused coping (28%). Lastly, while not being frequent either, we still identify some guests who coped by seeking social support (1%). For example, one guest describes how a staff member "even gave me a demonstration of the "robot" butlers that bring items to the rooms" (OR#10).

Finally, our analysis uncovers reference to the four types of post-purchase outcomes that we coded. Even in reviews, a type of unstructured data, the first post-purchase outcome of relational service well-being appears multiple times (1%). For example, both OR#14 and #15 describe how the customers felt being taken seriously during their HRI. Similarly, the second post-purchase outcome of switching intention is explicitly referred to in the ORs (1%), for instance in OR #16. Multiple reviewers (e.g., OR#17) also describe how the robot influenced the third post-purchase outcome of repurchase intentions (2%). Finally, we consider the voluntary inclusion of service robot experiences in ORs by hotel guests indicates a tangible manifestation of post-purchase behavior, specifically demonstration of our fourth post-purchase behavior of word-of-mouth communication. In fact, some reviews even directly recommend making use of the robot (e.g., OR#19) or to visit the hotel just to experience the robot (5%). Building on these insights, we next formulate our conceptual model.

3.4. HYPOTHESES DEVELOPMENT AND CONCEPTUAL MODEL

The conceptual background and Study 1 findings inform our hypotheses and conceptual model (Figure 3). To understand how customers cope with HRI during collective service experiences, we propose a model showing how different appraisals provoke varying coping strategies, resulting in a shared reality among customers that ultimately affects post-purchase outcomes.

3.4.1. Appraisal and outcome variables

Many ORs reflect challenge and threat appraisals. Challenge appraisals are generally associated with positive emotions, such as excitement, while threat appraisals are associated with negative emotions, such as anger, fear, or anxiety (Lazarus & Folkman, 1984). We know that positive as well as negative emotions during service encounters in general (e.g., Lin & Liang, 2011) and especially during those involving HRI (e.g., Pantano & Scarpi, 2022) significantly influence post-purchase outcomes, such as customer satisfaction, behavioral intentions, and emotional attachment. If customers perceive HRI as a potential loss (Lazarus & Folkman, 1984), they may be more inclined to switch providers. Conversely, if they see it as a gain, they might be less likely to switch. Appraising HRI as a loss could also make customers feel undervalued or treated less fairly, harming their relational service well-being. In contrast, perceiving HRI as a gain might lead to positive feelings, such as appreciation for the provider's investment in technology to enhance service. This could improve relational service well-being. Based on this reasoning and aligned with Study 1 findings (e.g., OR#14-19), we hypothesize that appraisals of HRI during service encounters directly affect post-purchase outcomes:

H1. Customers who develop challenge appraisals of HRI experience (a) greater relational service well-being and (b) lower switching intention.

H2. Customers who develop threat appraisals of HRI experience (a) lower relational well-being and (b) increased switching intention.

3.4.2. Appraisal and coping

Challenge appraisal. In Study 1, customers used both problem-focused and emotion-focused coping strategies after challenge appraisals. With a problem-focused coping strategy aimed at attaining a positive outcome (Duhachek *et al.*, 2012; Lazarus & Folkman, 1984), their action-oriented response (Duhachek, 2008) pursues maximal potential gains from the interaction with the service robot, as exemplified in OR#5. If instead they adopt emotion-focused coping strategies, customers strive to recognize and regulate their emotional responses. While such emotion regulation is often associated with loss aversion (Duhachek *et al.*, 2012), in the case of challenge appraisals, it can also lead to more positive emotional evaluations of the HRI (Bagozzi *et al.*, 2022). For example, in OR#9, the customers seek to understand, express, and regulate their positive emotions. Furthermore, we predict the use of a third coping strategy (i.e., social support seeking) to obtain informational or emotional support (Folkman *et al.*, 1986), as seen in OR#11, where after a challenge appraisal (i.e., robot as a means to get her late snack) the customer requires social support to use it. Consequently, we predict that challenge appraisals of HRI prompt customers to use social resources to acquire information or advice that enables them to attain a positive outcome.

H3. Customers who develop challenge appraisals of HRI exhibit (a) problem-focused coping, (b) emotion-focused coping, and (c) social-support seeking.

Threat appraisal. Also in the case of threat appraisals, customers appear to use problem-focused coping, emotion-focused coping and social support seeking. For example, in OR#8, a customer changes their perspective on the service robot to cope with their fear, while in OR#6, the customer takes direct action to fix the situation. We thus expect both types of coping strategies in response to HRI threat appraisals. Furthermore, the social nature of HRI during collective service experiences encourages customers to cope with threats by seeking social support (Folkman *et al.*, 1986). As illustrated in the opening quote, the frightened husband could have sought his spouse's help. Therefore, we expect customers to deal with threat appraisal by seeking informational and emotional support from others nearby (Folkman *et al.*, 1986; Folkman & Lazarus, 1985).

H4. Customers who develop threat appraisals of HRI exhibit (a) problem-focused coping, (b) emotion-focused coping, and (c) and social-support seeking.

3.4.3. Coping and shared reality

Coping with HRI in service frontlines involves social dynamics, as customers often act in the presence of others. Noting extant research (De Keyser *et al.*, 2020) showing that interactions shape people's perceptions of reality, we argue that coping with HRI during collective service experiences encourages the development of a shared reality. Employ problem-focused coping strategies (Han *et al.*, 2016), customers might purposefully take direct action and interact with the service robot together. Such collaborations encourage a shared reality, in the form of a collective understanding of the robot's capabilities and limitations. Alternatively, watching others interact with the robot can also cultivate a shared reality. If customers engage in emotion-focused coping (Han *et al.*, 2016), they likely use humor or positive self-talk to alleviate frustration or anxiety. For example, a customer might joke about the robot's efficiency (or lack thereof). Such interactions contribute to a shared reality of the service robot. Finally, social support seeking by definition means turning to others for assistance or guidance (Folkman *et al.*, 1986). A unique aspect of collective service experiences is their social context, where other group members can act as situationally available, external resources (De Keyser *et al.*, 2020). By seeking and receiving support, customers should begin to develop a shared understanding of the robot's role and capabilities and their own roles in interacting with it, enhancing the shared reality concerning the service robot.

H5. (a) Problem-focused coping, (b) emotion-focused coping, and (c) social support seeking all exhibit positive relationships with the development of a shared reality.

3.4.4. Shared reality and post-purchase outcomes

The importance of a shared reality, discussed earlier, is grounded in its capacity to influence post-purchase outcomes within collective service experiences. For instance, in OR#13, a family has developed a shared reality of the robot (i.e., all loving it), which they claim is a main reason to revisit the hotel. Such outcomes align with insights from Rossignac-Milon *et al.* (2021), who argue that a shared reality related to an object or event, shapes customer behavior and loyalty. Specifically, having a shared understanding of service robots enhances users' sense of predictability and self-efficacy (Hardin & Higgins, 1996). Here, we argue that predictability lowers customers' perceived risk, which reduces switching providers (Han *et al.*, 2011). Furthermore, higher self-efficacy has been found to boost continuance intentions (Thakur, 2018), which especially during potentially anxious interactions with novel technologies such as service robots (Echterhoff *et al.*, 2009), can foster improved customer experiences and thus lower switching intentions (e.g., Imbug *et al.*, 2018). Therefore, we expect that customers who developed a shared reality will be less likely to switch service providers.

Moreover, an enhanced self-efficacy also positively affects customers' perceptions of service value (McKee *et al.*, 2006) and their evaluative and behavioral response to a technological innovation or smart product (Ellen *et al.*, 1991). As a result, we argue that self-efficacy in HRI, resulting from a shared understanding of the service robots, leads to trusting, feelings of being treated fairly and taken seriously by the service provider. Thus, shared reality is expected to positively influence relational service well-being.

H6. A shared reality about the service robot (a) enhances relational service well-being and (b) lowers switching intention.

Figure 3.3 depicts the conceptual model and its hypotheses.

3

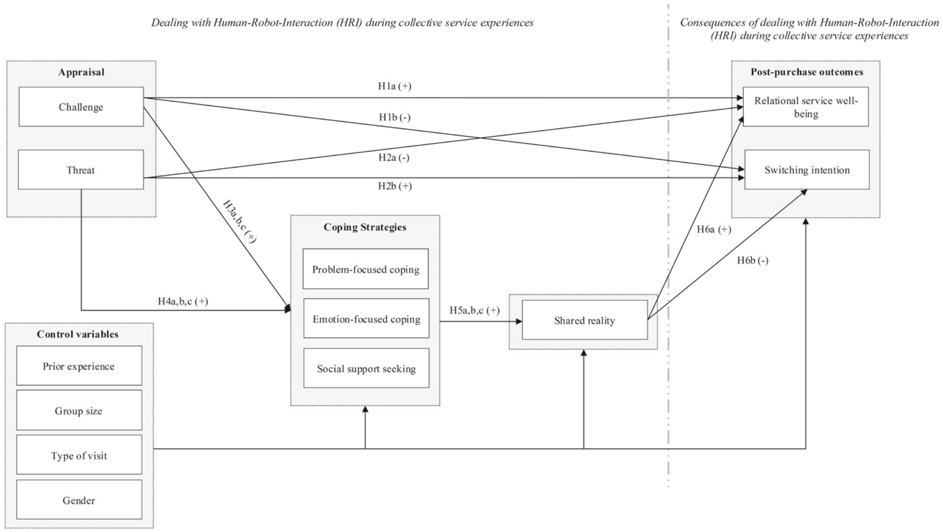

Figure 3.3. Conceptual model and hypotheses

3.5. STUDY 2: VALIDATING THE CONCEPTUAL MODEL IN THE FIELD

3.5.1. Methodology

To validate the conceptual model, Study 2 features a quantitative approach, based on real-life data collected in a fast casual restaurant in Western Europe. This restaurant, with a maximum capacity of 210 guests, employs four identical service robots (**Figure 3.4**). All four robots serve drinks and food and return used dishes to the kitchen. They communicate with customers via voice technology (e.g., instruct customers to take the food from their trays).

Figure 3.4. Robot in study 2

Procedure. To enhance response rates and data quality, we provided instructions to FLEs distributing surveys. Instructions were given to staff, displayed behind the bar, and in the staff area of the restaurant. Moreover, one researcher briefed employees at a staff meeting before data collection began and was present for the first two weeks of the study.

After seating, distributed an informational flyer about the research (**Appendix 3.2**). However, staff invited customers to participate in the study only after they had completed their main course, ensuring interaction with the robot before survey responses. Participating customers received a voucher with survey access via QR code (**Appendix 3.3**) and could claim a surprise gift on completion t (e.g., Asian-style salt-and-pepper mill). Survey items (see **Appendix 3.4**) were presented in a randomized order, all based on prior research, adapted to fit the context, and using 7-point Likert scales (1 = "strongly disagree," 7 = "strongly agree"). **Appendix 3.4** reports the scale reliabilities. Informed by relevant prior research, we included prior experience, group size, type of visit, and gender as control variables (Neal & Griffin, 2006; Odekerken-Schröder *et al.*, 2022; Rossignac-Milon *et al.*, 2018).

Sample. Data was collected from November 22–December 25, 2022. After excluding 77 respondents (19.8%) who failed the attention check and two respondents who dined by themselves (0.5%), 310 customers remained (68.9% female; 70.3%

younger than 44 years). All respondents were served by a service robot, and 81.6% had previously visited the restaurant. They mostly visited the restaurant in groups of two (52.6%) or three to four people (30.6%), accompanied by friends (36.8%), family (33.5%), or partners (24.8%).

Data analysis. To test the hypotheses, we used partial least squares structural equation modeling (PLS-SEM), an estimation technique based on ordinary least square regressions that can predict hypothesized relationships and maximize the explained variance in the dependent variables (Hair *et al.*, 2016).To apply it, we leverage SmartPLS 4 software (Ringle *et al.*, 2022), with conventional, recommended algorithms and settings; missing variables were treated with case-wise deletion (Hair *et al.*, 2019).

To assess the possibility of common method bias, we followed Kock's (2015) procedure for PLS-SEM research. The highest variance inflation factor (VIF) is 1.67, well below the recommended threshold of 3.3, so common method bias does not appear to be a significant concern (Podsakoff *et al.*, 2003).

3.5.2. Results

Measurement model: validity and reliability. To ensure construct reliability, we examined the item loadings, composite reliabilities, and Cronbach's alphas. All measures met the established threshold levels for acceptability, indicating satisfactory reliability. Detailed results are provided in **Appendix 3.4**.

Structural model: hypotheses tests. We assessed the structural model and path coefficients using a bootstrapping procedure with 5,000 samples (Hair *et al.*, 2011). Among the control variables, type of visit and prior experience showed no significant effect on any endogenous variables ($p > .05$), except for frequent visitors (three times or more), who exhibited a negative correlation with switching intention ($\beta = -0.494$, $p < .01$) and a positive effect on relational service well-being ($\beta = .475$, $p < .01$). Group size influenced coping strategies negatively for groups of five or more (e.g., problem-focused $\beta = -.386$, $p < .05$; emotion-focused $\beta = -.452$, $p < .001$; social support $\beta = -.643$, $p < .001$), with no effect on shared reality, customer service well-being or switching intention. Lastly, while gender generally showed no significant influence on endogenous variables (p > .05), we did reveal a negative effect on shared reality for female respondents ($\beta = -.296$, p < .01).

Turning to the estimation results, we refute our prediction of a positive effect of challenge appraisals on relational service well-being ($\beta = .115$, $p > .1$, $f^2 = .01$) and thus reject H1a. Nor do we find support for challenge appraisals affecting switching intention in H1b ($\beta = -.092$, $p > .1$, $f^2 = .01$). However, threat appraisals are linked negatively to relational service well-being ($\beta = -.258$, $p < .001$, $f^2 = .07$) and positively to switching intention (β = .158, $p < .05$, $f^2 = .02$) as per H2a and H2b. Challenge appraisals positively affect problem-focused coping (β = .335, $p < .001$, $f^2 = .10$), emotion-focused coping (β = .424, $p < .001$, $f^2 = .16$), and social support seeking (β = .332, $p < .001$, $f^2 = .10$), supporting H3a, H3b, and H3c. Threat appraisals did not influence problem-focused coping (β = .080, $p > .1$, $f^2 = .01$) or social support seeking (β = -.024, $p > .1$, $f^2 < .01$), refuting H4a or H4c, but promoted emotion-focused coping (β = .197, $p < .01$, $f^2 = .04$) as predicted in H4b. Direct paths from emotion-focused coping (β = .192, $p < .05$, $f^2 = .03$) and social support seeking (β = .176, $p < .05$, $f^2 = .02$) to shared reality support H5b and H5c, yet no support exist for problem-focused coping influencing shared reality (β = .064, $p > .1$, $f^2 < .01$) in contrast with H5a. Finally, shared reality positively affects relational service well-being (β = .187, $p < .01$, $f^2 = .04$) and negatively affects switching intention (β = -.148, $p < .05$, $f^2 = .02$), confirming H6a and H6. **Figure 3.5** and the last table in **Appendix 3.4** summarize these results.

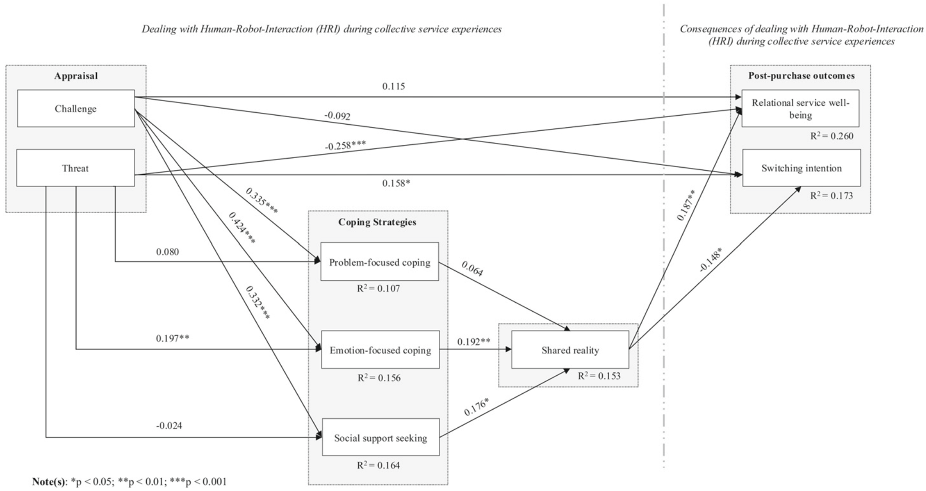

Figure 3.5. Structural model and results

3.6. DISCUSSION

3.6.1. Theoretical implications and further research

This study aims to capture the social context surrounding HRI in real-life service frontlines by investigating customers' appraisal, coping and shared reality perceptions about the service robot within collective service experiences. By doing so, it advances existing research beyond the typical focus on dyadic interactions, which neglects the social context in which HRI at the service frontline occurs in real-life (cf. Lu *et al.*, 2020). For instance, while Song and Kim (2022) discuss how individual users assess retail service robots, we find that HRI often occurs collectively in settings like hospitality (Torres, 2015), education (Conway *et al.*, 2009), and healthcare (Glisson *et al.*, 2008). Drawing on appraisal theory and building on recent calls for an enriched understanding of real-life HRI at the service frontline (Mende *et al.*, 2019), we analyze 1107 online hotel reviews, which affirm that customers rarely experience HRI individually. Instead, during their collective service experiences, they exhibit appraisal and coping mechanisms that affect their post-purchase outcomes. Moreover, some reviews suggest that groups of customers develop a shared perspective regarding the service robot. Based on these observations, we propose and empirically test a conceptual model among 310 customers served by robots in a fast-casual restaurant. The findings indicate the emergence of a shared reality about the service robot, driven by customers' appraisal and coping strategies to navigate HRI at the service frontline. Specifically, those who cope through social exchanges—expressing emotions (emotion-focused) or seeking help (social support seeking)—are more likely to develop this shared reality compared to those using action-oriented (problem-focused) strategies.

Despite the neutral tone, the emergent shared reality generally led to positive post-purchase outcomes. Perhaps the feeling of interpersonal support that consumers experience in developing this shared reality leads to self-efficacy in HRI (Echterhoff *et al.*, 2009; Tschannen-Moran & Hoy, 2007), explaining these results. The data may also reflect views from loyal customers with low threat appraisals—yet even a mere shared perspective enhances relational service well-being (Falter & Hadwich, 2020) and reduces switching intention. Continued research thus should examine whether shared reality benefits less loyal customers or customers who perceive HRI as more threatening.

An unanticipated consequence of HRI pertains to threat appraisals, which lead to emotion-focused coping, but not to action-based coping or social support seeking, perhaps due to embarrassment (Pitardi *et al.*, 2022). Customers feeling incompetent with service robots, prompting threat appraisals, might develop a sense of embarrassment (Wu & Matilla, 2013). As post-purchase outcomes depend on how customers appraise and cope with HRI, future research should investigate the antecedents of and contextual factors driving these threat appraisals and coping strategies. Besides earlier mentioned customer characteristics (e.g., loyalty), also robot characteristics (e.g., service role and tasks) might impact appraisals and coping. Moreover, future research should identify ways to encourage customers to seek help and express themselves about HRI.

Furthermore, customers perceiving service robots as threats report reduced relational service well-being and stronger switching intentions, so attempts to improve frontline experiences by infusing them with service robot technology have the potential to backfire (van Doorn *et al.*, 2017), with unintended negative consequences. This highlights the need to consider such unintended outcomes when designing and deploying HRI systems, particularly in service industries, where customer well-being (e.g., education and healthcare) and loyalty (e.g., hospitality and financial services) are key. Scholars should identify to what extent and under which conditions infusing service robot technology in service frontlines enhances or hinders the customer experience.

Lastly, the control variables revealed some interesting findings. Expectedly, repeat customers—particularly those visiting three times or more—show a lower likelihood to switch and a stronger sense of relational service well-being. Surprisingly, previous visits did not affect HRI-related appraisal or coping behaviors, possibly due to variable group dynamics in collective service experiences. For instance, a customer might visit multiple times, but with different groups or under different circumstances. In larger groups, fewer individuals may interact with service robots, possibly explaining the reduced HRI-related coping reported by individuals in groups larger than four. These findings underscore the importance of not only examining individual perceptions within groups, as our study has done, but also the collective dynamics and the interplay between individual and group experiences. While our findings are robust for controlling for the group size and focusing on groups with two responses in our data set, future research would benefit from focusing on the nested nature of collective service experiences and employ a multilevel approach (Raudenbush and Bryk, 2002).

3.6.2. Managerial implications

Although van Doorn *et al.* (2017) highlight the importance of a robot' social presence, the social complexity of groups of customers interacting with robots remain underexplored. Our findings suggest that a joint perspective on HRI significantly influences customers' post-purchase outcomes. To optimize these, service providers should expand their focus beyond dyadic human–robot interactions, to include multiple humans–robot interactions (HsRI) or even humans–robots interactions (HsRsI). Our results advocate for providers to: (1) actively mitigate threat (loss) appraisals and promote challenge (gain) appraisals. Specifically, customers who view HRI as menacing, yet refrain from coping, manifest increased switching intentions and reduced relational service well-being; (2) facilitate customer coping during HRI, which, during collective service experiences, shapes a shared reality about the robot that is beneficial to managerially relevant post-purchase outcomes; and (3) foster shared realities about the service robot. In the following, we elaborate on initiatives aligned with these implications.

Appraisals. Merely deploying robots at service frontlines is not enough to sustain customer engagement with HRI. Service providers should reduce threat (loss) appraisals and enhance challenge (gain) appraisals. For example, staff might accompany first-time users of service robots and actively offer support by explaining how to interact with the robot, rather than waiting for a request for help. Furthermore, our findings suggest that especially challenge appraisals lead customers to share their feelings about HRI during collective frontline experiences, fostering a beneficial shared perspective on the service robot. Encouraging these positive appraisals can prompt more customer interaction with frontline service robots. For example, emphasizing the benefits of the robotic service (e.g., fast, consistent, convenient) and how it elevates the customer experience. While this recommendation to improve the customer experience might appear evident, service providers, given the nascent stage of robot technology, often focus on functional implementation rather than optimizing customer interactions with service robots.

Coping. Besides steering appraisals, service providers should aid customer coping in collective service experiences by offering resources like visual aids—tabletop tablets or interactive displays—that provide information and detail robot functionalities. Such initiatives enable customers to independently explore the robot, potentially minimizing perceived incompetence or lack of self-efficacy and thereby preventing embarrassment in HRI while empowering them to engage with the technology on their terms. Additionally, while our study highlights social support among customers, frontline employees (FLEs) should also proactively engage and assist customers. This smooths HRI and simultaneously fosters a shared reality among customers, thereby contributing to beneficial service outcomes.

Shared reality. Effectively integrating robots at service frontlines, particularly in collective settings, involves cultivating a shared understanding of the robot among customer groups. Beyond aiding in coping with HRI, which drives shared realities, service organizations should educate customers about the robot's role. For example, managers could develop a standardized but adaptable approach to introduce service robots to customers. Providing clear explanations about the robot's capabilities, limitations, and purpose are likely to contribute to the formation of a joint perspective within customer collectives. Alternatively, robots could be programmed to self-introduce 'friend', 'helper' or 'assistant', thereby leveraging the technology to set and manage customer expectations. Such initiatives could foster a shared reality about the robot's role and purpose within customer collectives, potentially improving customers' evaluations of self-efficacy in dealing with HRI, leading to beneficial post-purchase outcomes such as decreased switching intention, and increased relational service well-being.

3.6.3. Limitations

In Study 1, we carefully selected ORs to include in the sample, but it is essential to acknowledge that OR mechanisms themselves may introduce biases into the data. Users leaving reviews might have unique motivations or experiences that differ from the broader customer base. Bias could stem from self-selection, where individuals with particularly positive or negative encounters with the service robot are more likely to post reviews. Additionally, the overall sentiment of ORs may not fully capture the nuances of customer perceptions, as text-based reviews often lack context and depth. Our reliance on ORs in Study 1 provided valuable insights. Nonetheless, this type of unstructured data does not provide access to contextual information (e.g., the precise circumstances under which HRI related appraisal and coping took place). Future research could incorporate ethnographic designs (e.g., interviews or observations) to gain a more holistic understanding of customer perceptions, coping and resulting outcomes.

In Study 2, the respondents were predominantly loyal customers who were already familiar with the service robot. While this familiarity allowed us to examine the impact of threat appraisals among a managerially highly relevant customer group, it might be limiting the generalizability of our findings. Loyal customers, having established a positive relationship with the restaurant and the robot over time, might perceive the robot's presence differently than new customers who lack prior exposure. This familiarity may have reduced the salience of perceived threats, potentially underestimating the negative impact of threat appraisals on post-purchase outcomes. Finally, our study primarily focuses on the overall impact of challenge and threat appraisals without delving into potential variations among individual appraisals. Future studies should investigate which specific threat dimensions, such as safety or self-efficacy concerns, are more influential in shaping customer attitudes and behaviors to provide more nuanced insights.

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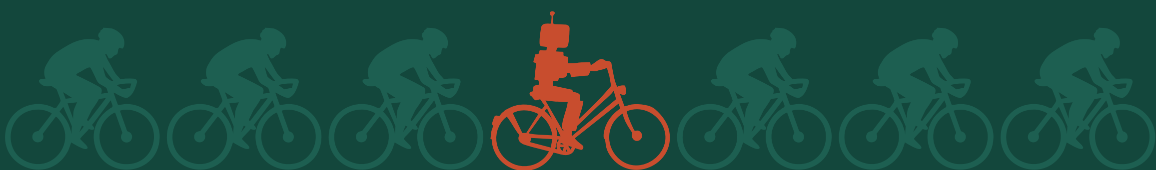
CHAPTER 4

THE IMPACT OF A TELEPRESENCE ROBOT ON GROUP CONDITIONS AND STUDENT ENGAGEMENT: A MIXED-METHOD STUDY IN HIGHER EDUCATION

In the case of this chapter:
Steins, M., Mennens, K., Beausaert, S., Mahr, D., Odekerken-Schröder, G., Mariş, A., Mathmann, F., (submitted). The impact of a telepresence robot on group conditions and student engagement in small-scale collaborative hybrid classrooms: A mixed-method field study in higher education. *The Internet and Higher Education.*



4.1. INTRODUCTION

The hybrid classroom has emerged as a vital model for inclusive and accessible education, aligning with Sustainable Development Goal 4 by synchronously combining on-site and remote participation (United Nations, 2024). This approach, especially popularized as institutions reopened post-COVID-19, supports students who face barriers related to work, health, or geography that prevent them from physically joining their education activities. The hybrid classroom offers them the chance to remotely participate in education and engage with instructors and peers (Ulla & Perales, 2022; Raes *et al.*, 2020b). Despite its potential, fostering an inclusive, cohesive environment that equally engages both remote and on-site students remains challenging (Saichaie, 2020), as remote students often experience isolation due to their physical separation from the classroom community Williamson *et al.*, (2020).

While this challenge affects educational contexts in general, it is especially pronounced in small-scale, collaborative learning settings, such as problem-based learning (PBL), which have been widely adopted due to their effectiveness for (team) learning and student performance (Tran, 2014). In these settings, group conditions, such as psychological safety, and student engagement are essential for successful collaboration to achieve learning goals (van den Bossche *et al.*, 2006). Yet, when remote students participate alongside their on-site team members, via a smart screen, the asymmetry of presence – being physically apart – may lead to reduced participation (Rovai, 2002) and feelings of isolation (Williamson *et al.*, 2020), ultimately threatening student engagement, collaboration, and learning outcomes (van den Bossche *et al.*, 2006). Recent empirical evidence supports these concerns, as Raes *et al.* (2020b) find that for remote students, the hybrid classroom is the most challenging environment for teaching and learning, with significantly lower levels of peer relatedness and intrinsic motivation. These challenges are particularly pronounced in collaborative hybrid learning environments, where learning relies on sustained social interaction and relationship building between team members. In such settings, the unequal opportunities for interaction between remote and on-site students undermine the critical socialization function of education (Biesta, 2020). This weakened socialization foundation places significant pressure on essential group conditions like psychological safety, potentially diminishing the collaborative knowledge construction and sharing that drives effective team-based learning (Van den Bossche *et al.*, 2006).

Acknowledging these challenges of the hybrid classroom, the adoption of new technologies might play a crucial role in successfully delivering education in these settings (García-Morales *et al.*, 2021). One promising innovation for supporting inclusive and equitable quality education for all students (Sustainable Development Goal 4, United Nations, 2024) is virtual inclusion via telepresence robots (TPRs; Kasuk & Virtus, 2023). Unlike traditional video conferencing tools that rely on fixed screens, TPRs offer remote students the ability to move around and interact with the classroom as if physically present, fostering a greater sense of physical presence and social connection, which may enhance inclusivity and reduce feelings of isolation (Fitter *et al.*, 2020; Nakanishi *et al.*, 2009; Newhart *et al.*, 2016). While initial TPR research demonstrates benefits for remote students, the technology's impact on the entire student group remains underexplored. This gap is particularly critical in small-scale collaborative learning settings, where successful learning outcomes depend on essential group conditions that enable active engagement and collaborative knowledge construction among all participants - both remote and on-site (Van den Bossche *et al.*, 2006). Furthermore, existing TPR research is limited both in scope - focusing primarily on remote students' experiences - and methodology, with most studies employing single-method approaches that may not capture the complex dynamics of these educational settings (Kasuk & Virkus, 2023).

This study addresses these gaps by investigating how TPRs influence group conditions and student engagement across all participants in small-scale collaborative hybrid classrooms. Through an explanatory sequential mixed-methods design (Creswell & Plano-Clark, 2018), we combine quantitative longitudinal analysis with qualitative inquiry to provide comprehensive insights into TPR effects. Our investigation centers on two research questions:

1. To what extent does a telepresence robot affect group conditions and student engagement in hybrid small-scale collaborative classrooms?
2. How does a telepresence robot affect group conditions in hybrid small-scale collaborative classrooms?

4.2. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

4.2.1. A social perspective on learning

The challenges of hybrid classrooms are particularly salient when viewed through the lens of socio-constructivist learning theory. The dominant learning theory socio-constructivism argues that learning is contextual, constructive, self-directed and collaborative (Zembylas, 2005). This theoretical foundation underscores why effective virtual inclusion is critical, as learning emerges through social interaction and collaborative knowledge construction. Keeping these principles in mind, higher education has been applying activating learning methods, such as problem-based learning, in which students work in small groups (collaborative), on real-life cases (contextual), through which prior knowledge is activated (constructive) and self-study is fostered when trying to overcome knowledge gaps (Hmelo-Silver, 2004). Research on pedagogical approaches in higher education has demonstrated the centrality of meaningful interaction among participants for effective learning outcomes (Mendo-Lázaro *et al.*, 2022). The integration of remote and on-site participants introduces additional complexity to these interactional dynamics. In a collaborative learning setting, individuals come together to work on a task simultaneously, aiming to learn from both the task itself and the teamwork involved (Van Den Bossche *et al.*, 2006). While co-presence provides a foundation for teamwork, successful collaborative learning relies on strong group conditions that enable effective coordination and knowledge sharing among all participants (Roschelle and Teasley, 1995).

4.2.2. Group conditions - Team beliefs about the interpersonal context

Research on collaborative learning environments has identified several essential group conditions that influence learning effectiveness (Van den Bossche *et al.*, 2006). These group conditions, also referred to as beliefs about the interpersonal context and interpersonal processes, are a key focus area in team-based learning literature, which emphasizes the social factors that drive successful group performance. Effective team learning and performance depend on group conditions, such as psychological safety, social and task cohesion, interdependence and group potency (Edmondson, 1999; Van den Bossche *et al.*, 2006). These team beliefs are of utmost importance for fostering team learning and performance (Decuyper *et al.*, 2010) and are particularly critical in hybrid environments where the asymmetry of presence between on-site and remote students might introduce additional complexity to these interpersonal dynamics (Raes *et al.*, 2020b).

At the foundation of effective group conditions lies *psychological safety*, which is "meant to suggest neither a careless sense of permissiveness, nor an unrelentingly positive affect but rather a sense of confidence that the team will not embarrass, reject, or punish someone for speaking up" (Edmondson, 1999, p.354). This confidence stems from mutual respect and trust among team members, which may be particularly challenging to establish in hybrid settings where physical separation can impede natural relationship development. Psychological safety facilitates learning behavior in teams because it alleviates excessive concern about others' reactions to actions that have the potential for embarrassment or threat, which learning behaviors often have. Learning in groups can be threatening and stressful for a multitude of reasons (van den Bossche *et al.*, 2006). People do not know each other, are left out, blame each other for mistakes, and so on. Edmonson (1999) highlighted the gravity of psychological safety as a facilitating interpersonal process for team learning behavior and thus indirectly group performance.

Next to psychological safety, cohesion plays a vital role in effective team learning. Cohesion is a multidimensional construct that has been widely studied as a key element of group functioning (Mullen & Copper, 1994; Van den Bossche *et al.*, 2006). *Social cohesion* refers to the nature and quality of the emotional bonds of friendship such as liking, caring, and closeness among group members. While *task cohesion* focuses on shared commitment to group goals, social cohesion specifically addresses the interpersonal connections that support sustained collaboration - a particular challenge when some team members are physically separated from others.

Similar to cohesion, *interdependence* is also a multidimensional construct. A distinction is made between task interdependence and outcome interdependence (Van den Bossche *et al.*, 2006). Task interdependence (initiated and received) refers to the interconnections among tasks such that the performance of one definite piece of work depends on the completion of other definite pieces of work. Outcome interdependence is defined as the extent to which team members' personal benefits and costs depend on successful goal attainment by other team members.

Finally, the last critical element for effective group functioning is *group potency*, representing the overall collective belief about the group's ability to be effective (Gully et al., 2002; Van den Bossche *et al.*, 2006). This shared confidence in the team's capabilities becomes especially relevant in hybrid settings where technological mediation might introduce additional complexity to group interactions.

In the context of hybrid classrooms, understanding how these conditions manifest when TPRs are utilized for virtual inclusion represents an important area of investigation. Unlike task cohesion and interdependence, which primarily relate to task completion and functional teamwork, psychological safety, social cohesion and group potency are essential for creating an inclusive, collaborative environment where remote students feel safe, connected and empowered. Therefore, we focus on how TPRs affect psychological safety, social cohesion, and group potency, as these factors are more likely to be directly impacted by virtual inclusion by a telepresence robot, providing the remote student a physical embodiment and mobility.

4.2.3. Telepresence robots to elevate group conditions in the hybrid classroom

Virtual inclusion of remote students through telepresence robots (TPRs) is increasingly being used in educational team settings (Kasuk & Virkus, 2023). They allow students who cannot physically attend on-site to participate remotely. Namely, TPRs provide a physical presence in the classroom through a robot equipped with two-way video and audio capabilities (Tsui, Desai, and Yanco 2012). In small-scale collaborative learning environments, such as PBL, TPRs could help overcome the challenges of hybrid classrooms by mitigating the asymmetry of presence between remote and on-site students through fostering co-presence (Bower *et al.*, 2014) and social interactions (Kristoffersson *et al.*, 2013). Specifically, TPRs have been used with the goal of creating a sense of “being there” and enabling individuals to maintain an embodied experience in the classroom, when their physical presence is not possible (Charteris *et al.*, 2024). Moreover, these robots may provide a way for students to remain connected to their institutes, classmates, and teachers, and to maintain or develop critical social relationships via virtual inclusion (Newhart *et al.*, 2016).

Different from traditional video conferencing through specially equipped rooms with smart screens and or laptops, TPRs enable a more dynamic form of virtual inclusion through physical embodiment and mobility in the classroom space (Kasuk & Virkus, 2023). This mobility allows remote students to navigate the learning environment independently, join different group configurations, and engage in informal social interactions - activities that are severely limited with fixed video screens. The ability to move and maintain eye-level interactions may help normalize the remote student’s presence and support more natural social dynamics, thereby creating more comparable learning experiences for all students, regardless of their location (Cain *et al.*, 2016). However, it is important to note that TPR implementation also presents potential challenges, including technical reliability issues, the cognitive load of robot operation, and the need for both remote and on-site participants to adapt to this new form of interaction (Charteris *et al.*, 2024).

Research on more traditional virtual inclusion through a smart screen on the wall has compared the experiences of on-site students and remote students and reveals that these two groups experience education differently in the hybrid classroom (e.g., Olt, 2018; Zydney *et al.* 2019). This is crucial to consider when designing the learning experience, as the primary goal of synchronous hybrid learning is to provide all students with comparable learning opportunities, regardless of their location (Butz *et al.*, 2016).

Yet, studies on virtual inclusion by TPRs have primarily focused on the remote students, as the increasing adoption of these robots in educational settings is driven by their potential to enhance the learning experience for them (Leoste *et al.*, 2022). For instance, Nakanishi *et al.* (2009) found that combining physical presence with movement enhances the online student’s perception of a social connection with the distant site. Fitter *et al.* (2020) found that students felt more present, self-aware, and expressive when using a TPR in comparison to traditional virtual inclusion using more mainstream distance learning tools (e.g., smart screen, camera, laptop).

However, especially in small-scale collaborative learning environments, where learning and performance are a result of group dynamics, teamwork and student engagement, the experience of all students, including those on-site, should be considered (Decuyper *et al.*, 2010). A class or group solely focusing on the remote students might adopt a slower pace with excessive repetition, thereby negatively affecting the learning experience of the on-site students (Bower *et al.*, 2015). In their recent systematic literature review on synchronous hybrid learning, Raes and colleagues (2020a) conclude that although promising, the challenges in hybrid classrooms lie in designing and implementing both pedagogical strategies and technological systems that enact comparable learning experiences (Cain *et al.*, 2016), also referred to as co-presence (Bower *et al.*, 2014).

Building on the theoretical foundations of collaborative learning and early evidence of TPR benefits, predominantly for the remote student, this research investigates the impact of a TPR on the other students in the hybrid classroom. We propose that TPRs will positively influence essential group conditions. Furthermore, consistent with previous research on team learning (Van den Bossche *et al.*, 2006), we expect these enhanced group conditions will support higher levels of student engagement. Specifically, we propose the following hypotheses:

H1: Students in hybrid classrooms that incorporate telepresence robots report enhanced group conditions, specifically in terms of (a) social cohesion, (b) psychological safety, and (c) group potency.

H2: (a) Social cohesion, (b) psychological safety, and (c) group potency are positively associated with higher levels of student engagement.

4.3. METHODS

4.3.1. Research Design

To address our research questions about the impact of TPRs on group conditions and student engagement, this study employed an explanatory sequential mixed-methods design (Creswell & Plano-Clark, 2018), starting with quantitative data collection and analysis, followed by qualitative data collection and analysis, leading to interpretation. The longitudinal quantitative dataset includes student responses to two online surveys administered in week 3 and week 5 of their 7-week course, examining the influence of the telepresence robot on group conditions at two time points. The qualitative dataset consists of 10 in-depth post-hoc qualitative interviews with on-sites students who experienced the virtual inclusion of remote students via the TPR in the hybrid classroom. Building on our theoretical framework focused on group conditions, we focused on the perceptions of the on-site students for two key reasons. Firstly, the majority of students in our sample attended class on-site, as per default students were required to be physically present. Secondly, their perspective offers valuable insights into how the TRP affects group conditions beyond the remote student's/ operator's experience, providing a broader understanding of its impact within the physical classroom environment.

4.3.2. Context and Participants

To examine our hypotheses about telepresence robots' effects on group conditions and student engagement, the quantitative study included 235 students from two graduate courses in Marketing and Supply Chain Management at a large European university. These courses were conducted in a collaborative hybrid classroom setting over a 7-week period in February and March 2022. Consistent with the collaborative learning principles outlined in our framework, students participated in two 2-hour problem-based learning (PBL) sessions each week, in groups of up to 15 students and one teacher. During these sessions, learning occurred collectively through active participation, collaboration, and knowledge co-creation. This study was conducted after institutions reopened post-COVID-19, with students required to attend classes on-site unless they exhibited symptoms or had been exposed to individuals infected with the virus. Using a quasi-experimental design, the students were divided over 17 tutorial groups. Eight tutorial groups were assigned to the experimental condition, with access to a telepresence robot throughout the course, while nine tutorial groups were assigned to the control condition, with no access to the telepresence robot. The participants were not informed of the study's research questions, ensuring they remained unaware of the study's purpose or focus, regardless of whether their group had access to the telepresence robot. For the qualitative study, 10 on-site students from the eight experimental groups who experienced the virtual inclusion of remote peers via the telepresence robot were interviewed to gain deeper insights into their experiences (see **Table 4.1**).

Table 4.1. The design of the explanatory sequential mixed-methods study

Data Type	Quantitative	Qualitative
Unit of analysis	Students in experimental and control groups	On-site students in experimental groups
Data source	Surveys in weeks 3 & 5	Interviews post course
Data analysis	PLS - SEM	Content analysis

4.3.3. Procedure and Technology

In alignment with socio-constructivist learning principles (Zembylas, 2005), PBL sessions at this large European university typically take place in rooms where tables are arranged in a square, so all on-site students face each other. Per default, remote students join via Zoom, displayed on a smart screen positioned on the wall. At the start of the course, students in the experimental condition were informed they could make use of the telepresence robot TEMI in case they needed to attend the PBL session remotely (see Table **2**). Only one student used the TPR at a time. If multiple students expressed interest in using it, priority was given based on two criteria: students who had not used the robot before were given preference, followed by a first-come-first-served basis. Students were provided with a detailed instruction manual for accessing and operating the TPR, which they controlled through their laptops or smartphones. Their device's camera captured their face, which was displayed on the robot's screen, and their voice was transmitted via the robot's audio system. As described in our conceptual framework, the TPR, equipped with a mobile screen and controlled remotely, allows students to see, hear, speak, and interact in real-time. The robot could move around the classroom, similar to a student in a wheelchair, and was generally positioned at one of the tables in the square. Remote students also had the ability to navigate the robot and control its gaze (See **Figure 4.1**).

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Table 4.2. Course set-up and overview of data collection procedure

Duration	Experimental Group	Control Group
Course set-up		
First week (w1)	Introducing the course and course content in plenary opening lecture	Introducing the course and course content in plenary opening lecture
For six weeks (w2-w7)	2 PBL sessions per week in a hybrid classroom with • on-site students; • remote students via Zoom on smart screen; • remote student via telepresence robot TEMI	2 PBL sessions per week in a hybrid classroom with • on-site students; • remote students via Zoom on smart screen;
Data collection procedure		
Week 3 & week 5	Survey at end of PBL session	Survey at end of PBL session
Post-course	Interviews with 12 on-site students	n/a

Figure 4.1. A hybrid collaborative classroom where a remote student is virtually included using telepresence robot TEMI

4.3.4. Quantitative data analysis

To test our hypotheses regarding the impact of the TPR on group conditions and engagement we used the longitudinal data from the two surveys in week 3 and 5. Participation was voluntary and rewarded with an additional course credit of 1.5 out of a maximum of 100 total course credits. Data from remote students who operated the telepresence robot were omitted, as this modality was exclusive to the experimental group, ensuring comparability between the experimental and control groups. After further eliminating respondents for incomplete answers or failed attention checks, a final sample of 156 students who participated in both surveys remained from the total student population of 235. We employed partial least squares structural equation modeling (PLS-SEM) to test our hypotheses. PLS-SEM is an estimation technique based on OLS regressions (Barrett *et al.*, 2021) and the decision to apply this method of analysis was driven by two main arguments: First, PLS-SEM can handle small sample sizes of less than 200 respondents (Hair *et al.*, 2019). Second, the method is nonparametric and thus can deal with nonnormal data (Molinillo *et al.*, 2018). Shapiro-Wilk and Kolmogorov-Smirnov tests, as recommended by Hair *et al.* (2019) indicate that all our endogenous variables are non-normally distributed. Therefore, we use PLS-SEM and more specifically SmartPLS 4 software (Ringle *et al.*, 2022). We used the algorithm and settings as recommended by Hair *et al.* (2019), and applied case-wise deletion for missing values.

4.3.5. Qualitative data analysis

The goal of the second study was to understand how virtual inclusion of a remote student by a TPR affects group conditions in small-scale collaborative hybrid classrooms. The study relies on 10 interviews with on-site students who experienced the virtual inclusion of their remote peers via the TPR throughout a 7-week period. We employed a combination of the critical incident technique (CIT; Flanagan, 1954) and qualitative content analysis, treating each mention of the robot as a critical incident that could offer relevant insights into how the robot affected group conditions.

We conducted the qualitative content analysis adhering to best practices outlined by Stemler (2001). First, we developed an a priori coding scheme for the study's core constructs: social cohesion, psychological safety, and group potency, based on van den Bossche *et al.*'s (2006) measures of these group conditions, and student engagement based upon work by Falter and Hadwick (2020). Aligning with our theoretical framework, the initial coding scheme enabled us to identify the relevant transcript sections and sequentially to contextualize the research model from study 1. Specifically, it allowed us to distill the key dimensions of the group conditions influenced by the robot. Based on this coding scheme, two authors independently analyzed the content of every interview to determine how group conditions were influenced by the robot. (Stemler, 2001). To analyze the data, we conducted a qualitative analysis following established inductive approaches (Creswell, 2007). The analysis process involved three distinct rounds: a priori coding of group conditions, open coding, and research/methodological coding (Bogdan & Biklen, 2003). We iteratively analyzed the data while examining relationships between emerging codes. This process allowed us to identify recurring patterns in the data, which were then collapsed into broader categories and finally synthesized into overarching themes. The research coding phase specifically aligned the analysis with our study's objectives, ensuring interpretations remained grounded in our second research question: *how* does a telepresence robot affect group conditions in hybrid small-scale collaborative classrooms. The final coding scheme and its application is detailed in **Table 4.6** in the results section.

4.4. RESULTS

4.4.2. Results from quantitative data analysis

In the next sections, we first assess our measurement model, which attaches manifest variables to their latent variables. After that, we test the relationships between our latent variables by evaluating the structural model (Fornell and Larker, 1981; Hulland, 1999)

Measurement model – validity and reliability

To ensure the reliability of the constructs under investigation, we utilized several measures, including item loadings, composite reliability, and Cronbach's alpha values. Our approach involved examining individual item reliability through item loadings **Table 4.3**, with a widely accepted threshold of 0.7 or higher (Aparicio et al, 2016) used to evaluate each item's loading. Our results showed that all items surpassed this threshold, with the exception of the psychological safety scale in T1, exhibiting a factor loading of 0.69 and thus closely approaching the commonly accepted threshold of 0.70 (Hair *et al.*, 2016).

In addition to evaluating individual item reliability, we also examined construct reliability. To establish construct reliability, Hair *et al.* (2016) recommended assessing composite reliability and Cronbach's alpha values, with values of 0.7 or greater being considered acceptable. As presented in **Table 4.4**, our findings demonstrated strong composite reliability values ranging from 0.84 to 0.90 and Cronbach's alpha ranging from 0.71 to 0.85, indicating that construct reliability was established.

Furthermore, all constructs have AVE values exceeding 0.50, indicating satisfactory convergent validity (Molinillo *et al.*, 2018). Discriminant validity was established using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio criterion (Barrett *et al.*, 2021). For the Fornell-Larcker criterion, each construct's square root of the AVE should exceed its correlation with other constructs and be higher than 0.7 (Chin, 1998). Our findings show that all constructs meet this criterion. The HTMT values were also below the accepted threshold of 0.85 (Voorhees *et al.*, 2016). Lastly, the measures were not threatened by multicollinearity, as the variance inflation factor values were all below the threshold level of 5 (Hair *et al.*, 2019).

Table 4.3. Constructs, items, and factor loadings T_1 and T_2

Construct (sources)	**Items**	**Standardized loadings T_1**	**Standardized loadings T_2**
Group Conditions			
Social cohesion (Van den Bossche ***et al.***, 2006)	SC1. I like my tutorial group	0.82	0.79
	SC2. I get along with members of my tutorial group	0.74	0.84
	SC3. I feel a sense of belongingness to my tutorial group	0.83	0.83
	SC4. I am friends with the members of my tutorial group	0.70	0.75
Psychological safety (Van den Bossche ***et al.***, 2006)	PS1. If you make a mistake in this tutorial group, it is often held against you - reverse coded	0.69	0.75
	PS2. It is difficult to ask other members of this tutorial group for help – reverse coded	0.72	0.76
	PS3. People in this tutorial group sometimes reject other peers for being different. – reverse coded	0.83	0.87

Table 4.3. Continued

Construct (sources)	Items	Standardized loadings T_1	Standardized loadings T_2
Group potency (Van den Bossche ***et al.***, 2006)	GP1. This tutorial group expects to be known as a highly performing group.	0.83	0.81
	GP2. This tutorial group believes it can become exceptionally good and successfully accomplish each assignment.	0.82	0.82
	GP3. This tutorial group believes it can be very effective.	0.82	0.85
	GP4. This tutorial group can get a lot done when it works hard	0.71	0.83
Outcome variable			
Engagement (Falter & Hadwich, 2020)	Please indicate to what extent you agree with the following statements concerning this tutorial meeting		
	EN1. During this tutorial meeting, I am interested	n/a	0.89
	EN2. During this tutorial meeting, I am attentive	n/a	0.84
	EN3. During this tutorial meeting, I am engaged	n/a	0.87

Table 4.4. Means, standard deviations, correlations and reliability estimates based on T_2

Construct	Mean	SD	AVE	CR	α	1	2	3	4
Social Cohesion	5.65	0.73	0.65	0.88	0.82	*0.80*			
Psychological Safety	6.21	0.75	0.63	0.84	0.71	0.49	*0.79*		
Group potency	5.61	0.76	0.69	0.90	0.85	0.67	0.36	*0.83*	
Engagement	5.65	0.79	0.75	0.90	0.84	0.56	0.39	0.52	0.87

Note(s): All constructs were measured on seven-point interval scales; SD = standard deviation; AVE = average variance extracted; CR = composite reliability; α = Cronbach's alpha. The square root of the average variance extracted for each construct is indicated in *italics* on the diagonal of the correlation matrix.

We assessed the model's predictive relevance by examining the effect size and explained variance of the endogenous constructs (Barrett *et al.*, 2021). Our findings, presented in **Table 4.5**, show that the R^2 values of the endogenous constructs range from 0.04 to 0.44, besides the group potency and psychological safety constructs in

T_1 exceeding 0.1 thresholds which, following Hair *et al.* (2019) is deemed satisfactory. Furthermore, in line with recommendations by Hair *et al.* (2016), we also reported the f^2 effect sizes, which ranged from 0.01 to 0.53, indicating small to large effects for the supported hypotheses. In summary, our results support the model's predictive relevance.

Structural model – hypothesis testing

We used a bootstrapping procedure with 5,000 samples (Hair *et al.*, 2011) to evaluate the structural model and test the significance of the path coefficients. Analysis of control variables revealed that gender, prior experience with telepresence robots, and experience with hybrid classrooms had no significant effect on any of the endogenous variables ($p > 0.05$) in T_1 and T_2. We also controlled for the modality of participation, finding that on-site students perceived significantly higher levels of social cohesion in T_1 ($\beta = 0.668$, $p < 0.01$), while no significant relationships were observed between modality and any other constructs. In T_2, modality of participation had a positive relation with group potency ($\beta = 0.469$, $p < 0.001$), social cohesion ($\beta = 0.469$, $p < 0.001$), and engagement ($\beta = 0.303$, $p < 0.05$).

The results indicated a positive effect of the TPR on social cohesion in T_1 ($\beta = 0.76$, $p < 0.001$, $f^2 = 0.17$), supporting H1a. We also found a positive relationship between the TPR and both psychological safety ($\beta = 0.41$, $p < 0.01$, $f^2 = 0.04$) and group potency ($\beta = 0.32$, $p < 0.05$, $f^2 = 0.03$) in T_1, supporting H1b and H1c. However, when controlling for the group conditions in T_1 no significant effects of the TPR were found in T_2 for social cohesion ($\beta = -0.10$, $p > 0.10$, $f^2 < 0.01$), psychological safety ($\beta = 0.19$, $p > 0.10$, $f^2 < 0.01$) and group potency ($\beta = 0.08$, $p > 0.10$, $f^2 < 0.01$). Therefore, we conclude to have found partial support for H1. We found support for the relationship between social cohesion in T_2 and engagement in T_2 ($\beta = 0.28$, $p < 0.01$, $f^2 = 0.06$), and for group potency in T_2 and engagement in T_2 ($\beta = 0.23$, $p < 0.05$, $f^2 = 0.05$), supporting H2a and H2c. However, no support was found for the relationship between psychological safety in T_2 and engagement in T_2 ($\beta = 0.15$, $p > 0.10$, $f^2 = 0.03$), and thus rejecting H2b. **Figure 4.2** and **Table 4.5** provide a summary of the results from the hypothesis testing.

Table 4.5. Results of hypotheses testing and explained variance

Hypothesized relationship	Standard path coefficient (*p*-value)	Hypothesis supported (S) or not supported (NS)	R^2 (construct)
H1: Robot intervention T_1 → Group conditions T_1			0.20 (Social Cohesion T_1)
H1a: Social Cohesion	0.76 (0.000)	S	0.05 (Psychological Safety T_1)
H1b: Psychological Safety	0.41 (0.007)	S	0.04 (Group Potency T_1)
H1c: Group Potency	0.32 (0.043)	S	
H1: Robot intervention T_2 → Group conditions T_2			0.44 (Social Cohesion T_2)
H1a: Social Cohesion	-0.101 (0.475)	NS	0.31 (Psychological Safety T_2)
H1b: Psychological Safety	0.187 (0.401)	NS	0.38 (Group Potency T_2)
H1c: Group Potency	0.081 (0.555)	NS	
H2: Group Dynamics T_2 → Engagement T_2			
H2a: Social Cohesion T_2	0.28 (0.006)	S	0.39 (Student Engagement T_2)
H2b: Psychological Safety T_2	0.15 (0.157)	NS	
H2c: Group Potency T_2	0.23 (0.014)	S	

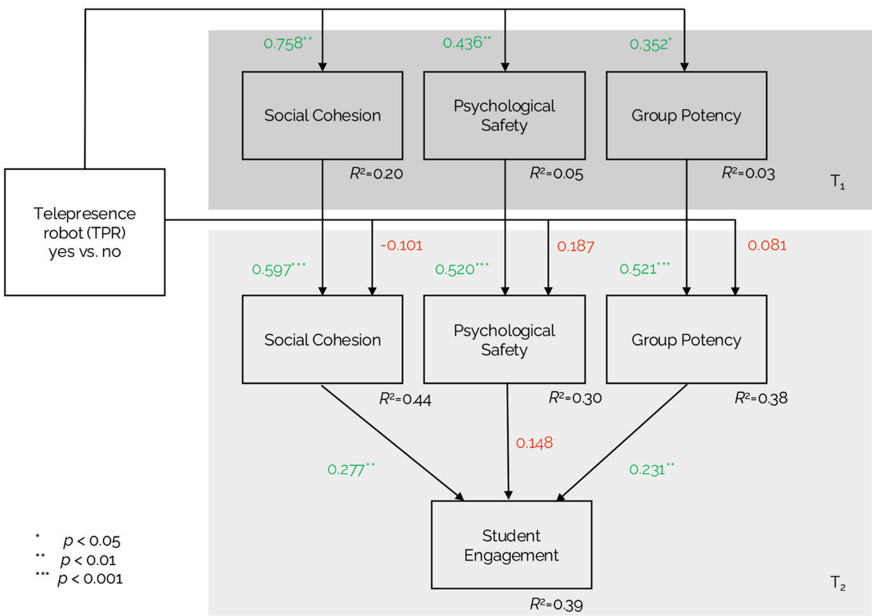

Figure 4.2. Structural model and results

4.2.2. Results from qualitative data analysis

Our analysis of student interview data revealed four interconnected themes that characterize the impact of telepresence robot technology on group conditions and learning in hybrid classrooms: (1) establishing presence through the telepresence robot, (2) facilitating interaction via the telepresence robot, (3) influence on group conditions, and (4) inclusivity in the hybrid collaborative classroom. Each theme emerged from both the experiences of on-site students and their perspectives on remote users' experiences. **Table 4.6** presents our complete coding scheme with frequencies, which provide an indication of how prominent each theme was in the interviews. The following sections detail these themes using verbatim participant quotes, with pseudonyms to ensure anonymity.

Table 4.6. Coding scheme and frequency of categories and indicators

Codes, categories & indicators	N meaningful units	N interviewees
1. Establishing presence through the telepresence robot		
A. *On-site student experience*		
1.A.1 Perceived presence	**186**	**10**
1.A.1.1 Physical presence/ embodiment	54	10
1.A.1.2 Movement/ mobility in classroom	51	10
1.A.1.3 Prominent position in room	31	9
1.A.1.4 Proximity to on-site students	15	5
1.A.1.5 Eye contact - on eye-level	12	7
1.A.1.6 Visibility of the remote student	23	9
B. *Perspective on remote user's robot experience*	**40**	**9**
1.B.1 Empowerment	14	4
1.B.1.1 Autonomy	9	6
1.B.1.2 Offering new opportunities	17	7
1.B.1.3 Signals interest in group meeting		
2. Facilitating interaction via the telepresence robot		
A. *On-site student experience*		
2.A.1 Ease of interaction	**75**	**10**
2.A.1.1 Interaction ease and convenience	35	8
2.A.1.2 Private and more casual conversation	16	6
2.A.1.3 Normalization and more natural conversation	24	8
B. *Perspective on remote user's robot experience*		
2.B.1 Remote student's engagement	**62**	**10**
2.B.1.1 Attentiveness in group meeting	14	6
2.B.1.2 Active engagement in group meeting	48	10

Table 4.6. Continued

Codes, categories & indicators	N meaningful units	N interviewees
3. Influence on group conditions		
A. *On-site student experience*		
3.A.1 Social cohesion	**66**	**10**
3.A.1.1 Group liking	4	2
3.A.1.2 Getting along with group members	2	1
3.A.1.3 Sense of belongingness	45	10
3.A.1.4 Group friendship	15	4
3.A.2 Psychological safety	**22**	**7**
3.A.2.1 Mistake tolerance	3	2
3.A.2.2 Ease of support seeking	12	6
3.A.2.3 Acceptance of differences	7	4
3.A.3 Group potency	**36**	**8**
3.A.3.1 High performance expectation	4	3
3.A.3.2 Belief in group excellence	7	3
3.A.3.3 Perceived group effectiveness	19	8
3.A.3.4 Productivity through effort	6	4
4. Inclusivity in the hybrid collaborative classroom		
4.A.1 Inclusivity	**55**	**10**
4.A.1.1 Willingness to include remote student	26	10
4.A.1.2 Reciprocity - matching efforts	16	6
4.A.1.3 Remote student perceived more valuable member	13	5

Establishing presence through the telepresence robot

Our analysis revealed two primary perspectives regarding presence: the on-site student experience (Code 1.A) and perspectives on remote users' robot experience (Code 1.B). Within these, several key subthemes emerged regarding how presence was established and perceived.

On-site student experience. Regarding perceived presence (Code 1.A.1), our analysis identified six key elements: physical presence/embodiment, movement/mobility, prominent positioning, proximity to on-site students, eye-level contact, and visibility of the remote student (Codes 1.A.1.1-1.A.1.6). Participants consistently highlighted how the robot's physical embodiment, its mobility, and its prominent position in the room facilitated a sense of connectedness between them and the remote student using the robot. Specifically, the robot's ability to move and its eye-level positioning created a more authentic sense of presence, as if remote students were physically present in the room. This perception emerged clearly in participant narratives: "*When TEMI was used, I was in the class and it was really like, I really felt like the person who* *was on TEMI was there, because they could move forward and backward, they were more present."* (Student 10).

Regarding embodiment and movement (Codes 1.A.1.1, 1.A.1.2), another participant elaborated on how subtle movements signaled the remote student's engagement: *"I can tell that they're listening as well, just because they moved their camera a little bit, like, okay. You know, that, to me says, oh, they want to get a better angle of the speaker, for example."* (Student 3).

The analysis further revealed that the choice to use the telepresence robot—rather than joining via a Zoom call on the smart screen—served as an indicator of the remote student's engagement, interest, and willingness to contribute actively to the hybrid group meeting. As one participant observed: "*Whenever someone joined via TEMI, they would actively participate in class and therefore my respect for that classmate increases because they want to, even though they're joining online. You noticed that because they joined via TEMI. They really want to participate in class and be there and be involved in discussions. Whereas with the zoomies, sometimes I just forget about them because some of them, you don't feel like they actively want to participate and are just sitting there."* (Student 1).

Perspective on remote user robot experience. Our analysis of empowerment (Code 1.B.1) revealed three distinct aspects: autonomy, new opportunities, and signals of interest in group meetings (Codes 1.B.1.1-1.B.1.3). Participants emphasized how the physical embodiment and mobility of TEMI afforded opportunities for demonstrating active participation that were not possible with traditional video calls. One participant articulates this distinction: "*With Zoom, you're more at the mercy of your teammates, you know, wherever they put you, a laptop or a screen is fixed. And that's all you can do. Like, 'Hey guys, I'm still here.' Whereas with TEMI, it's like, you can really show yourself where you want to go*" (Student 3).

The data further provided insights about the remote student's level of autonomy resulting from joining via TEMI: *"There's only one person in that robot. Right. So, the robot is fully controlled by the person. So, in that sense, um, I think, yeah, more autonomy… like there are more opportunities for the person to actually participate actively in the discussion rather than just being one of the five or seven people that are online captured on a screen."* (Student 9).

This empowerment, manifested through enhanced presence, greater autonomy, and increased opportunities for remote students to actively participate, was crucial in setting the stage for improved interactions between on-site and remote students in the hybrid classroom.

Facilitating interaction via the telepresence robot

The enhanced perceived presence and empowerment of the remote student established through TPR TEMI (Theme 1) created foundations for improved interactions between remote and on-site students. Our analysis identified two major categories: the on-site experience of interaction ease (Code 2.A.1) and evidence of remote student engagement (Code 2.B.1).

On-site student experience. Regarding ease of interaction (Code 2.A.1), three key elements emerged: general interaction convenience, capability for private conversations, and normalization of communication (Codes 2.A.1.1-2.A.1.3).The data indicated that TEMI enabled remote participants to interact more naturally, seamlessly contributing to group discussions and engaging in informal conversations. Moreover, TEMI's mobility emerged as a crucial factor in allowing dynamic, context-driven conversations, enhancing remote students' opportunities for active participation in group work. These dynamics were well captured by Student 3 and Student 7: *"I would imagine if the person using TEMI, you know, they want to have good communication with their teammates. And so they'll adjust accordingly. Whereas with Zoom, it's like, 'Oh, hey, can you fix this? And this, it's not, I'm not hearing well.' But with TEMI, it was just more the responsibility of the user to do it"* (Student 3). This shift in responsibility, where remote students were empowered to adjust their own positioning, fostered more fluid and natural interactions. In terms of interaction convenience and normalization (Codes 2.A.1.1, 2.A.1.3), participants noted how TEMI's mobility enhanced spatial flexibility: *"TEMI would move to the area where the group work is happening. And then it's a little bit easier to have some kind of conversation because they can see you as a smaller group. You can see them. Um, and it's easier to maybe, uh, direct and say, hey, I'm talking to you. What do you think? … it was more seamless and easier to coordinate those conversations".* (Student 7). This enhanced spatial flexibility, afforded by the telepresence robot, proved instrumental in facilitating meaningful interactions in group activities. Furthermore, the remote student's empowerment through TEMI corresponded with increased engagement and active participation, thereby enhancing the interaction potential with on-site peers. The following participant refers to the usefulness perception of the telepresence robot: *"A remote student on TEMI could participate in the class much more compared to joining via zoom. So, we kind of saw this transition of, "oh, the robot is a fun little team member" to something that was very practical and functional for us."* (Student 4).

Perspective on remote user robot experience. Regarding remote student engagement (Code 2.B.1), two key factors emerged: attentiveness and active engagement (Codes 2.B.1.1-2.B.1.2). Our analysis reveals that attentiveness and active engagement foster a heightened sense of responsibility among remote students, leading them to take greater ownership. *"I would imagine that the person using*

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TEMI wants to have good communication with their teammates. And so, they'll adjust accordingly. Whereas with zoom, it's like, "oh, hey, can you fix this? And this, it's not, I'm not hearing well." There are all these awkward adjustments sometimes. But with TEMI, it was just more the responsibility of the user to do it. And in that way, it was a bit easier to communicate, I would say." (Student 3).

The enhanced presence and empowerment of remote students (theme 1), alongside improved interactions between on-site and remote students facilitated by the telepresence robot (theme 3), seemed crucial in fostering positive group conditions within the hybrid classroom. The following section examines the influence of the telepresence robot on the collaborative learning climate by examining its influence on the group conditions.

Influence on group conditions

In line with our research question and results from our quantitative study, we examined how the TPR influenced the group conditions. Building on those, our analysis presents the three distinct types of group conditions: social cohesion (Code 3.A.1), psychological safety (Code 3.A.2), and group potency (Code 3.A.3). Our analysis of the influence on group conditions revealed varying degrees of impact across the three types of group conditions examined. Social cohesion emerged as the most prominently discussed condition (66 meaningful units), followed by group potency (36 meaningful units), and psychological safety (22 meaningful units). This distribution suggests that the telepresence robot may have had its strongest influence on social aspects of group dynamics.

Social cohesion. Our analysis of social cohesion revealed four key indicators: group liking, getting along with group members, sense of belongingness, and group friendship (Codes 3.A.1.1-3.A.1.4). Notably, sense of belongingness emerged as the most frequently referenced dimension of social cohesion (45 meaningful units). The interviews demonstrated how the ease of interaction and engagement facilitated by TEMI the telepresence robot transformed remote participants into integral members of the hybrid classroom. This enhanced integration was particularly evident in participants' reflections on a sense of belonging and strengthened interpersonal bonds: *"I felt more united. So there's a more emotional connection because versus the students on zoom, there's no emotional connection… more of a feeling of, yeah, you're part of this group, because normally with the zoomies, I would not really have that because they don't talk a lot. But, now it feels a little bit more personal"* (Student 1). The data revealed how enhanced connections, reflecting the development of sustained relationships (Code 3.A.1.4), persisted beyond individual sessions: *"Whenever you would talk to your classmates, you form this connection with each other, and whenever they would come back to class, I would remember who has joined via TEMI and know* *the person a little bit better in comparison to those who were just sitting quietly there in Zoom"* (Student 1). These findings highlight how the telepresence robot, by fostering closer interpersonal connections and a stronger sense of belonging, contributes to the development of social cohesion within hybrid learning environments.

Psychological safety. Though discussed less frequently than the other conditions (22 meaningful units), analysis of psychological safety identified three key aspects: mistake tolerance, ease of support seeking, and acceptance of differences (Codes 3.A.2.1-3.A.2.3). Within these aspects, ease of support seeking emerged as the most prominent factor (12 meaningful units). The telepresence robot played a crucial role in developing a stronger sense of psychological safety within the hybrid classroom environment. The data revealed that enhanced psychological safety emerged through distinct behavioral patterns. Specifically, students demonstrated increased comfort in seeking support and displayed a heightened willingness to engage and contribute, regardless of whether they were participating remotely or in person. The enhanced psychological safety fostered ease of interaction for all students in the hybrid classroom, as the following participant noted: *"When someone is on TEMI, it feels more natural to approach them and ask questions, as opposed to when they're on Zoom and disconnected from the group."* (Student 3).

Regarding barriers to participation (Code 3.A.2.3), participants noted how TEMI helped overcome traditional hybrid learning challenges: *"I think there's maybe sometimes a kind of barrier. when you are online. That you have the feeling - okay, I don't need to contribute, the others will solve it or make the exercise. But I believe those barriers are less present when a remote student joins via TEMI. It might be easier to evaluate if and maybe more importantly when their contribution is desirable"* (Student 10). These findings underscore how telepresence technology can facilitate a more psychologically safe learning environment by reducing participation barriers and enabling more natural interactions between remote and on-site students, and easing the process of seeking and offering support.

Group potency. While discussed less frequently than social cohesion, group potency emerged as the second most prominent condition in our analysis (36 meaningful units). Our analysis of group potency is based upon four indicators: high performance expectations, belief in group excellence, perceived group effectiveness, and productivity through effort (Codes 3.A.3.1-3.A.3.4). Within these indicators, perceived group effectiveness was most frequently cited (19 meaningful units), suggesting this was a key mechanism through which the telepresence robot enhanced group potency. The telepresence robot facilitated enhanced group potency through its ability to enable meaningful contributions from remote participants, which resulted in a higher perceived group effectiveness. This was particularly evident in the ways remote students were able to engage more fully in knowledge construction

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and sharing. As one participant observed: *"… they (referring to remote student on TEMI) would actively participate in discussions. And then new insights are acquired and it's better to have a discussion. And whenever that happened, I felt like the tutorials were enhanced in terms of knowledge and knowledge sharing"* (Student 1). Similarly, another participant highlighted the importance of the telepresence robot in strengthening overall group participation: *"TEMI includes a bit more the person online and that's not only relevant for the one online, but also for the ones that are on-site, because it's all, in the end, it's us, the students that contribute to or make a good tutorial. So, everything that improves the presence of the participation is welcome"* (Student 6). These insights underscore how the telepresence robot played a vital role in increasing self-belief and the perceived contribution and engagement of all members, thereby enhancing group potency in the hybrid classroom.

Inclusivity in the hybrid collaborative classroom

Our analysis revealed broader implications of telepresence technology beyond immediate group conditions (theme 3), particularly regarding group inclusivity. Our analysis revealed broader implications for group inclusivity (Code 4.A.1), manifesting in three key aspects: willingness to include remote students, reciprocity in matching efforts, and perception of remote students as valuable members (Codes 4.A.1.1-4.A.1.3). On-site students demonstrated more inclusive behaviors towards remote students through these distinct but interconnected mechanisms. Regarding reciprocity and effort matching (Code 4.A.1.2), participants described a mutual reinforcement of engagement. The presence of TEMI facilitated enhanced integration of remote participants in discussions, fostering a more reciprocal relationship between on-site and remote students: *"We're putting effort in as well because they're putting effort in… and so when there's like that reciprocation of effort, then mine increases as well."* (Student 3). This mutual effort contributed to a shared responsibility for ensuring that all group members, whether on-site or remote, had equal opportunities to contribute. Furthermore, the evolution in remote student perception (Code 4.A.1.3) emerged as an interesting finding, with on-site students recognizing TEMI users as valuable contributors rather than peripheral zoom participants on a smart screen. This transformation was evident in observations like: *"… they would actively participate in discussions, and new insights are acquired. The tutorials were enhanced in terms of knowledge and knowledge sharing."* (Student 1).

The combined analysis of inclusivity indicators (Code 4.A.1) revealed that this recognition of remote students as valuable contributors, coupled with reciprocal inclusion efforts, created a self-reinforcing cycle of inclusion that enhanced both individual contributions and collective achievement within the hybrid classroom.

4.5. DISCUSSION

This mixed-methods study investigated how telepresence robots influence group conditions and student engagement in hybrid collaborative classrooms. The findings reveal several key insights about the role of telepresence technology in fostering virtual inclusion and enabling more effective hybrid learning environments.

4.5.1. Temporal effects on group conditions in the hybrid classroom

Study 1's quantitative results demonstrate that TPRs positively influenced group conditions, particularly in the early stages (T_1) of the course, suggesting that TPRs might establish essential foundations for collaborative learning. This role aligns with Silberstang and Diamante's (2007) emphasis on the critical importance of facilitating team conditions during the initial inertia phase of team development. During this formative period when group dynamics are being established, the TPR appears to accelerate the development of psychological safety, social cohesion, and group potency - creating conditions that become self-sustaining over time. The diminished effects in T_2 support this interpretation, indicating that once group conditions are established, the mode of virtual inclusion of remote students may become less critical for maintaining them. This temporal pattern highlights the particular value of TPRs in overcoming the initial barriers of hybrid classrooms and supporting the crucial early development of group conditions that enable effective collaborative learning in the hybrid classroom.

4.5.2. Mechanisms supporting enhanced group conditions in the hybrid classroom

The qualitative findings from Study 2 demonstrate how TPRs facilitate improved group conditions through two key mechanisms: enhanced presence and empowered participation of remote students. The physical embodiment and mobility afforded by the robot created a more authentic sense of presence for remote students, consistent with previous research on telepresence technologies (Fitter *et al.*, 2020; Nakanishi *et al.*, 2009). This enhanced presence, combined with the autonomy to navigate the physical space, enabled more natural interactions between remote and on-site students. These findings extend Bower *et al.*'s (2014) work on co-presence by demonstrating how TPRs can help overcome the presence asymmetry that often characterizes hybrid learning environments by facilitating more natural interactions.

4.5.3. Implications for collaborative learning theory

Our findings contribute to socio-constructivist learning theory and our understanding of collaborative learning in hybrid environments by demonstrating how technological affordances can influence essential group conditions. The results support Van den Bossche *et al.*'s (2006) emphasis on the importance of psychological safety, social cohesion, and group potency, while extending this framework to consider how these conditions manifest in technology-mediated learning environments. By demonstrating how TPRs empower remote students and enhance their perceived presence, they facilitate greater engagement among remote users. This, in turn, fosters easier interactions between on-site and remote students, positively influencing group conditions in hybrid classrooms. The positive relationship between enhanced group conditions and student engagement further validates the interconnected nature of social and learning processes in collaborative settings (Biesta, 2020).

4.5.4. Practical implications for hybrid education

For educators and institutions implementing hybrid learning, these findings suggest that TPRs can be valuable tools for creating more inclusive and effective learning environments, particularly in small-scale collaborative settings. Our quantitative findings suggest that TPRs could be deployed strategically during formative periods when group conditions are being established. However, the qualitative findings at the same time highlight how TPRs support both remote and on-site students in interacting and learning with each other in hybrid classrooms. Importantly, while TPRs may serve as catalysts for early group formation, their benefits in facilitating natural interactions and fostering inclusive behaviors persist throughout the course, suggesting their sustained value beyond initial implementation periods.

4.6. CONCLUSIONS, LIMITATIONS AND FUTURE DIRECTIONS

This study advances our understanding of how TPRs can support virtual inclusion in hybrid collaborative classrooms. The mixed-methods approach revealed both the quantitative impact on group conditions and student engagement, as well as the qualitative mechanisms through which these effects occur. The findings demonstrate that telepresence robots (TPRs) can help overcome traditional barriers to virtual inclusion and enhance the quality of interactions between on-site and remote students by improving the perceived presence and participation opportunities of remote students. Social cohesion, psychological safety, and group potency—key group conditions investigated in this study—benefit significantly from virtual inclusion via TPRs, compared to traditional virtual inclusion through a fixed screen, particularly during the critical early stages of group formation.

Several limitations should be noted. First, the study focused on a specific educational context with graduate students, namely small-scale collaborative hybrid learning in business courses, potentially limiting generalizability. Future research could conduct similar studies in other disciplines and pedagogical settings, e.g., project education. Second, while our data included students nested within groups, the sample size was insufficient to conduct meaningful group-level analyses that could reveal how telepresence robots influence collective learning processes and outcomes. Future research could extend this work by examining TPR effects at the group level of analysis. Such investigations could reveal how group-level phenomena - such as collective efficacy, shared mental models, and team learning behaviors - rather than individual perceptions only are influenced. This higher-level analytical perspective would provide valuable insights into how TPRs shape not just individual experiences, but collective learning processes in hybrid educational environments. Third, the presence of multiple remote students participating via traditional video conferencing alongside the TPR user may have influenced the overall group dynamics in ways not fully captured by our analysis. Future research could examine settings where all remote students use either telepresence robots or traditional video conferencing exclusively, allowing for clearer comparisons between these modalities. Studies could also investigate how remote students using different participation technologies interact with each other, potentially revealing important dynamics that influence overall group cohesion and engagement.

Despite these limitations, this sequential mixed-methods study makes important contributions to our understanding of virtual inclusion in higher education, demonstrating how TPRs can support more equitable and engaging hybrid learning experiences. These insights are particularly valuable as institutions continue to develop flexible learning options that align with the objectives of SDG 4, which advocates for inclusive, accessible, and equitable quality education and lifelong learning opportunities for all (United Nations, 2024).

4.7. REFERENCES

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CHAPTER 5

FACILITATORS AND BARRIERS TO SUSTAINED USE OF SOCIAL ROBOT IVY FOR PEOPLE WITH INTELLECTUAL DISABILITIES: A QUALITATIVE STUDY ON HEALTHCARE PROFESSIONALS' EXPERIENCES

In the case of this chapter:
Steins, M., Huijnen, C., Odekerken-Schröder, G., Mahr, D., Mennens, K., Daniels, R., and Mathmann, F., (submitted). Facilitators and Barriers to Sustained Use of Social Robot Ivy for People with Intellectual Disabilities: A Qualitative Study on Healthcare Professionals' Experiences. *Journal of Medical Internet Research.*

5.1. INTRODUCTION

Labor shortages in the healthcare sector pose significant challenges to sustaining high-quality care worldwide. According to the World Health Organization, a global shortage of 10 million healthcare workers is projected by 2030, with the quality of care heavily dependent on the availability, accessibility, and expertise of healthcare workers (WHO, 2024). In mental health care, these challenges are further amplified by the growing demand for care services for people with intellectual disabilities (PwID), which places additional strain on already overstretched resources (Wottiez *et al.*, 2018). This pressing reality threatens the sustainability of high-quality, person-centered care for PwID. In response, there is growing interest in technological solutions that could help address staffing shortages while maintaining the envisioned care.

Reflecting this growing interest in technological solutions, intelligent assistive technologies (IAT) are increasingly being used to support care for PwID (Torrado *et al.*, 2020). These empowering technologies, aimed at maintaining or improving an individual's functioning and independence, and thereby promoting their well-being, include a range of digital devices, ranging from smart home systems and tablets to wearable devices and humanoid robots (Boot *et al.*, 2018; Mahmoudi Asl *et al.*, 2023). Among these technologies, social robots have emerged as a particularly promising innovation. These robots have the potential to offer support to various target groups with complex needs, addressing a wide range of domains in daily life, including communication, social interaction, interpersonal relationships, emotional well-being, and functioning in everyday contexts (Huijnen *et al.*, 2019; 2021).

Systematic reviews in mental health care suggest that social robots have the potential to improve mood, social interaction, and activity participation for individuals with intellectual disabilities through both verbal and non-verbal interactions (Guemghar *et al.*, 2022; Hirt *et al.*, 2021). However, challenges such as unmet expectations, time constraints, limited technical capabilities, and ethical concerns have been reported, highlighting the need to carefully manage implementation processes to ensure long-term success (Blindheim *et al.*, 2022). These preliminary insights underscore a pressing need for empirical studies that examine both implementation processes and outcomes to better understand the potential role of social robots in mental healthcare, address implementation enablers and barriers, and determine their value for PwID and their personal caregiver(s). So far, few robots are fully designed and deployed in long-term care, and hence the opportunities to conduct this necessary research have been limited.

One notable example of a social robot that is already operational in the care process is Ivy, recently implemented as part of a regional collaborative initiative across six care organizations in the Netherlands (CZ Zorgkantoor, 2023.; Mahr *et al.*, 2024). Ivy is designed to support and accompany PwID in their daily lives, whether in care facilities or at home, by stimulating cognitive functions through personalized interactions. By doing so, Ivy also intends to support healthcare professionals by enhancing efficiency, enriching client care, and contributing to greater work satisfaction. Healthcare professionals can customize Ivy to tailor its support to each client's needs, providing assistance with their daily structure, personalized reminders for appointments and medication, and facilitating social interactions. The robot communicates through time based preprogrammed verbal interactions and displays supportive visual information on its screen.

The care organizations decided to introduce these social robots to their clients with intellectual disabilities due to Ivy's intended impact on both clients and healthcare professionals. Its real-world deployment offers a unique opportunity to examine the value created by the robot for PwID and their professional caregivers, as well as the facilitators and barriers influencing its ability to create value for these two key stakeholders.

Implementing robots in health- and long-term care settings is inherently complex (Mahr *et al.*, 2024), with little evidence guiding their use (Hung *et al.*, 2023). To understand the implementation process and outcomes, we draw upon two complementary theoretical frameworks. First, the NASSS framework (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability) helps to analyze implementation challenges across multiple interacting domains: the condition, the technology, the value proposition, the adopter system (comprising professional staff and clients), the organization(s), the wider context, and the interaction between these domains over time (Greenhalgh *et al.*, 2017). This framework categorizes implementation challenges as simple (straightforward, predictable barriers that are easily addressed), complicated (multiple interacting components requiring significant work to overcome), or complex (dynamic, unpredictable barriers that may lead to abandonment if not effectively managed).

Second, we employ Meiland *et al.*'s (2004) theoretical model for tracing facilitators and barriers in the adaptive implementation of innovations in care settings. This model examines implementation across four phases (preconditions, preparation, execution, and continuation) and three levels (micro, meso, and macro). While preconditions and preparation were addressed prior to our study, we focus specifically on the execution and continuation phases at the micro level, examining how the end-users, clients with intellectual disabilities and professional caregivers, experience and use robot Ivy over the first two months of implementation.

Together, these frameworks guide our investigation of both facilitators and barriers to successful adaptive implementation. To begin, the NASSS framework allows us to classify barriers by their level of complexity and likely impact on sustained use.

By applying the same classification framework to facilitators as we do to barriers, we can better assess their relative impact on the success of implementation. We analyze these facilitators and barriers separately for each key stakeholder (i.e., PwID and healthcare professionals), while also considering contextual factors unique to each implementation case and organizational factors. In the case of social robot Ivy, this categorization can help identify which facilitators to strengthen or further leverage, as well as which barriers to continued robot use are straightforward and manageable versus those that require more sophisticated support strategies. In this study, we apply these complementary frameworks to analyze the adaptive implementation of social robot Ivy in care for PwID, focusing in particular on micro-level factors within the adopter system domain (PwID and healthcare professionals), and the technology and value proposition domain (perceived value for these users). However, as we are investigating both the execution and continuation phases of implementation of social robots across 19 PwID and their professional caregiver(s) in actual productive care environments, our analysis also includes contextual and organizational factors from the caregiver's perspective, offering implications for the broader healthcare organization. Through semi-structured in-depth interviews with healthcare professionals (in this study also referred to as professional caregivers) after two months of implementation, we generate an understanding of facilitators and barriers to successful implementation, categorizing them by their level of impact on sustained use. We investigate the staff perspective, as their perceptions play a key role in the adoption of social robots (Papadopoulos *et al.*, 2020; Servaty *et al.*, 2020). Our research questions are:

1) What value does sustained use of social robot Ivy create for PwID and healthcare professionals?
2) What facilitators and barriers influence the continuation versus abandonment of social robot Ivy during the execution and continuation phases of implementation?

- What client and healthcare professional characteristics influence sustained use?
- What contextual and organizational factors affect implementation success?

5.2. METHODS

5.2.1. Study Design, Participants, and setting

This study was conducted between April 2023 and October 2023 across six care organizations in the southeast region of the Netherlands. A qualitative design was employed to assess the added value and user-friendliness of the social robot Ivy, as well as to identify facilitators and barriers to its sustained use for PwID receiving care under the Long-Term Care Act (Dutch: Wet langdurige zorg; Rijksoverheid, n.d.). The study followed 19 robot Ivy devices implemented within these care settings. Data were collected through semi-structured in-depth interviews with key stakeholders. While multiple stakeholder groups were involved in the implementation of the robot—including clients, healthcare professionals, and relatives and/or legal representatives—this study specifically focused on the perspectives of healthcare professionals. As they played a central role in introducing and integrating Ivy into daily care, their insights provided the most consistent and detailed account of the implementation process. Clients' cognitive limitations posed challenges for conducting meaningful or extensive in-depth interviews, and relatives were generally less engaged in the robot's daily use. Therefore, we recruited healthcare professionals who were directly responsible for introducing and integrating robot Ivy into client care. Participants were selected through purposive sampling, ensuring a diverse representation of perspectives across the participating organizations. The qualitative approach allowed for an in-depth exploration of how Ivy was integrated into daily care routines, the perceived value and challenges, and the contextual factors influencing long-term adoption.

The clients had moderate to severe intellectual disabilities requiring 24-hour care or continuous supervision. This population includes individuals with a congenital or later-developed disorder in intellectual functioning who also experience limitations in adaptive behavior, such as conceptual, social, and practical skills, as described by Schalock *et al.* (2010). Throughout this study, we use the terms PwID and clients interchangeably to refer to people with intellectual disabilities, with 'client' denoting their status as recipients of care services. For context, clients were eligible to use the robot if they: (1) had sufficient visual, auditory, and cognitive capabilities to process information from the robot, (2) could maintain appropriate attention to interact with the robot, and (3) were residents at one of the participating care organizations.

In total, we studied 19 unique cases, each comprising a robot implementation with a client and their involved healthcare professional(s). For each case, we conducted interviews with the healthcare professionals two months after the robot was implemented.

5.2.2. The technology - Robot Ivy

Robot Ivy (**Figure 5.1**) is a lightweight, small-size stationary social robot that healthcare professionals can customize through a browser-based platform to support each client's needs, providing clients assistance with their daily structure, personalized reminders for appointments and medication, and facilitating social interactions (Mahr *et al.*, 2024; RobotCTRL, n.d.). As such, the technology consists of two distinct interfaces, namely the physical robot which faces PwID and healthcare professionals, and the browser-based online platform where healthcare professionals set up and customize client interactions.

The client-facing interface consists of the physical robot itself, which communicates with clients through a human-like voice, which can be accompanied by pictograms and text on its touch screen. While Ivy communicates through spoken messages, it does not respond to voice commands. Clients can interact with Ivy through the touch screen and receive various types of personalized support, such as daily structure, appointment and medication reminders, cognitive stimulation, entertainment, social interaction, and companionship. Whenever the robot is not offering an interaction to the client, it displays a friendly, dynamic face to maintain an engaging and approachable presence (see Figure 1). The robot requires its own access point for internet connectivity and operates independently from existing healthcare information systems. Ivy executes pre-programmed tasks without independent decision-making capabilities.

Healthcare professionals design and customize client interactions through a separate browser-based online platform, which allows them to tailor interactions specifically for the needs of individual clients. Interactions can either be scheduled at specific time slots for plannable care (e.g., a morning routine), or made available for proactive activation by clients (e.g., when a client wants the robot to tell a joke or help communicate on their behalf). This interface allows healthcare professionals to configure and continuously adapt various types of interactions including reminders, questions, stories, display of photos and music playback using voice-only communications, voice with touch screen response options or voice with pictogram responses.

Figure 5.1. Robot Ivy

5.2.3. Data collection

In this research we investigated 19 cases of robot implementation, meaning 19 individual PwID who made use of a social robot Ivy. Data were collected through semi-structured in-depth interviews with the healthcare professionals responsible in those cases, which were conducted two months after robot Ivy got introduced to their respective client. The interviews explored professionals' experiences with implementing the robot, perceived value and user-friendliness for both staff and clients and factors influencing whether the robot's use was continued or discontinued after the initial implementation period.

The interviews lasted approximately 45-60 minutes each and were conducted by two researchers (authors MS and CH). Most interviews were conducted face-to-face and audio recorded. Some interviews were conducted via Microsoft Teams video conferencing due to scheduling constraints and were video recorded. While most interviews were one-on-one, four cases involved multiple professionals in group interviews (where multiple professionals were involved in implementing Ivy for that particular PwID). The 2-month timing allowed for a systematic and meaningful evaluation of the experiences of healthcare professionals and the identification of key facilitators and barriers influencing sustained use versus non-adoption or abandonment, in line with our theoretical frameworks (NASSS and Meiland).

5.2.4. Data analysis

All interviews were (audio/video) recorded and transcribed verbatim. A structured thematic analysis was conducted, guided by Meiland *et al.*'s (2004) implementation model and the NASSS framework (Greenhalgh *et al.*, 2017). Codes for facilitators and barriers per stakeholder (e.g., PwID/ client & healthcare professional), as well as contextual and organizational factors were created. The type of barriers resulted from the NASSS framework (Greenhalgh *et al.*, 2017) and are categorized as deal-breakers (high impact or complex), obstacles (medium impact or complicated) and minor hurdles (low impact or simple). Facilitators were constructed to mirror the severity of impact that these barriers have on sustained use (high/ medium/ low) and are categorized as key drivers, enablers, and minor boosters.

To ensure coding reliability and develop a shared understanding of the data, three researchers independently coded five interview transcripts. Through detailed discussion of discrepancies, the team developed a consistent interpretation of the coding framework, which guided one researcher in coding the remaining transcripts.

5.2.5. Ethical considerations

The study was approved by the Medical Ethics Review Committee (In Dutch Medisch Ethische Toetsingscommissie Zuyderland-Zuyd; Zuyderland, n.d.) and is known under approval number METCZ20230028. Written informed consent was obtained from all participants. Participants were informed they could withdraw from the study at any time without consequences for their employment.

5.3. RESULTS

5.2.1. Participants

In total, 19 interviews were conducted with 23 healthcare professionals, all of whom were directly involved in implementing 19 social robot Ivy devices as part of their clients' care. Of these professionals, 19 (82,6%) identified as female, and 4 (17,4%) identified as male. **Table 5.1** presents the distribution of research participants across cases nested in the six care organizations. The presentation of cases follows a chronological order, representing the sequence of data collection. One professional (#1) participated in two separate cases, as this caregiver was responsible for the direct care of two clients using the robot. While most interviews were conducted one-on-one, in four cases (cases 1, 6, 9, and 12), multiple professionals participated in group interviews, as they were all involved in the implementation of social robot Ivy for a client in those cases.

Table 5.1. Research participants across cases and across care organizations

Case	Care organization	Research participants
1	A	#1, #2
2	F	#3
3	F	#4
4	B	#5
5	C	#6
6	D	#7, #8
7	C	#9
8	A	#1
9	C	#10, #11

Table 5.1. Continued

Case	Care organization	Research participants
10	A	#12
11	F	#13
12	F	#14, #15, #16
13	F	#17
14	B	#18
15	E	#19
16	E	#20
17	A	#21
18	A	#22
19	D	#23

5.3.2. Sustained use of Social Robot Ivy

Answering the first research question, this section presents our findings on the value of sustained use of social robot Ivy, based on healthcare professionals' perspectives after two months of implementation. The robot demonstrated distinct value for both PwID and healthcare professionals.

Value for PwID

For PwID, the primary value emerged in three areas: (1) enhanced daily structure through consistent reminders and routines, (2) improved emotional well-being through non-judgmental interactions and companionship, and (3) increased independence in daily activities through empowerment.

(1) Enhanced daily structure. As professionals noted the robot supported in providing an enhanced daily structure, as illustrated by several quotes. *Using Ivy has enabled the client to independently start their day, which increases their self-confidence and saves us as professionals time and energy"* [#1].

"The robot provides structure which gives her more independence, and her emotional well-being has improved. The robot has become like a friend to her" [#3].

(2) Improved emotional well-being. The robot's value for emotional well-being was particularly evident through its role as a companion and source of non-judgmental support. The robot's emotion-free and non-judgmental communication proved particularly valuable for clients who tend to interpret human interactions negatively

or seek excessive validation. As one professional explained: *"Ivy is just the same every day, she doesn't need to shop around between me or a colleague if she gets a 'no' from one person and wants a 'yes' from another. So, I think that provides a lot of peace. And Ivy is just the same every day, she can't negotiate with it. I think that also provides a piece of clarity and peace"* [#8].

This consistent, neutral communication style helped reduce anxiety-inducing dynamics that could arise from varying responses between different care professionals, while providing clear structure and boundaries. Healthcare professionals observed that the robot contributed to building clients' self-confidence, reducing restlessness, and promoting emotional attachment.

(3) Increased independence through empowerment. According to one healthcare professional: *"We do this because he is very proud to mention that care staff no longer needs to come in with him, he is very proud that he can now do this independently. So his self-confidence is growing"* [#1]. The robot provided support in daily activities like getting up on time, brushing teeth, showering, eating, drinking, and taking medication, which increased clients' control over their daily routines and enabled them to perform certain tasks independently. Moreover, beyond fostering greater independence for PwID, the increased autonomy supported by the robot also has meaningful implications for both clients and caregivers. One healthcare professional highlighted how the robot reduces their need for constant reminders, reinforcing the client's sense of control and dignity: "*Of course, we are not always with her, and the fact that we no longer have to give certain reminders helps. I'm not going to remind her to take her medicine, if I know she already got the reminder from Ivy. That would be redundant and unnecessary [...] It gives her control and autonomy, and with that, a sense of self-worth*" [#3]. Another healthcare professional described how the robot actively encourages social participation: *"We notice that the robot encourages him to join the group, to ask others what his needs are"* [#7].

Value for healthcare professionals

For healthcare professionals, the value manifested in several ways: (1) reduced workload through automation of routine tasks, (2) improved quality of client interactions by freeing up time for meaningful engagement, (3) reduced emotional burden by having the robot absorb repetitive client interactions, and (4) enhanced work satisfaction through more efficient care delivery.

(1) Reduced workload through automation of routine tasks. Healthcare professionals reported that Ivy helped them achieve a better balance between delivering efficient care and maintaining meaningful human interactions. As one professional explained: *"For us as professionals, it's about the tasks it performs without us having to repeat instructions to the client over and over. This allows us to be with the client at other*

moments, and instead of saying 'do this, do that,' we can say 'come, let's have a coffee together.' Ivy has already handled the rest - that's our gain" [#13].

(2) Improved quality of client interactions by freeing up time for meaningful engagement. Furthermore, professionals highlighted how the robot reduced workload while improving client relationships: *"Yes, the moments that Ivy takes over, like waking up and medication reminders, reduce our workload. Ivy also provides structure and clarity, which makes the relationship with the client more stable"* [#7].

(3) Reduced emotional burden. The robot's ability to handle repetitive client interactions without emotional fatigue was particularly valuable. As one professional noted: *"Where staff might have an emotional reaction after hearing the same story multiple times... that will never happen with Ivy"* [#9].

(4) Enhanced work satisfaction through more efficient care delivery. Additionally, the robot's 24/7 availability provided valuable support during staff absences, ensuring continuity of care and allowing professionals to focus more on personalized support. See the quote by research participant #3 in the section on "*increased independence through empowerment*", where this participant highlighted how the robot reduces the caregivers' need to give constant reminders, reinforcing the client's sense of control and dignity.

In some cases, the robot contributed to a more stable environment and improved client well-being. As a result, staff spent less time managing crises, enabling them to prioritize meaningful engagement and individualized care for clients. For healthcare professionals, benefits emerged when the robot successfully engaged clients. During these moments of engagement, staff gained opportunities to attend to other care tasks. As one professional stated: *"In those ten-fifteen minutes you are again a bit more available for others. So, I do see the advantages in that."* [#15].

However, the extent of value creation and perceived value for clients as well as healthcare professionals varied significantly across cases. Healthcare professionals defined client-specific care goals for the robot prior to implementation, with these goals fully achieved in 5 cases, partially achieved in 6 cases, and not achieved in 8 cases. After two months, the robot remained in use for 12 clients while it was discontinued for 7 clients, demonstrating that certain conditions need to be met for sustained use. Having multiple cases of both outcomes proved highly valuable for investigating facilitators and barriers, enabling a more nuanced understanding of the factors influencing the sustained use of the robot.

5.3.3. Facilitators and Barriers to Implementation of Social Robot Ivy

Following our theoretical frameworks, we categorized both facilitating and impeding factors affecting the sustained use of robot Ivy. For barriers, following the NASSS framework, we classified them into three categories: deal-breakers, which often lead to non-adoption or abandonment; obstacles, which require significant effort or time to overcome; and minor hurdles, which are relatively easy to address. To mirror the impact of these barrier levels, facilitators are categorized as key drivers, enablers, and minor boosters.

In the following, guided by the second set of our research questions, we present our findings across four key areas that emerged from the data: (1) client-related factors, examining characteristics and needs of PwID that influence robot use; (2) healthcare professional-related factors, focusing on staff experiences and capabilities; (3) contextual factors, exploring implementation conditions across the 19 cases; and (4) organizational support factors, addressing meso-level elements that enable or hinder implementation of social robot Ivy in the micro environment, with end-users. **Table 5.2** provides a comprehensive overview of these client, healthcare professional, context and organizational related facilitators and barriers. The following sections present findings on these four key areas, highlighting frequently occurring and impactful facilitators and barriers, supported by illustrative quotes from our interviews with healthcare professionals. While our research primarily focused on micro-level implementation factors related to the end-users (Clients and their healthcare professionals), the interviews with healthcare professionals also revealed broader organizational, meso-level influences on sustained use of social robot Ivy and thus implementation success.

Client-related factors influencing sustained use of robot Ivy

Client characteristics and behaviors emerged as crucial determinants of successful robot implementation. All interviews around the 19 cases revealed that certain client traits consistently facilitated or impeded sustained robot use, particularly regarding cognitive capabilities, care needs predictability, and receptiveness to technological intervention. These characteristics significantly influenced whether the robot could effectively support clients' daily activities and emotional well-being. The following elaborates on frequently mentioned and impactful factors across the interviews, with numbers corresponding to their listing in **Table 5.2**.

As highlighted by several healthcare professionals, matching client needs with robot capabilities was essential for successful implementation. Most professionals emphasized key driver 1.1 - sufficient cognitive capabilities: *"There are moments that Ivy gives an instruction and then the client executes that, but there are also still many moments that it doesn't work. We are still looking at what exactly this is due to? Does the client not hear it or does the transition still pose difficulties?"* [#22]. Impactful deal-breakers to the sustained use of the robot include clients experiencing distress, mental health challenges, or instability (barrier 1.6), resulting in reduced or no capacity to engage with Ivy. This was observed in clients at risk of epileptic seizures, those relapsing into substance use, displaying compulsive behaviors, or experiencing negative emotions. As one professional noted: *"Client XYZ is currently doing so poorly that he's not open to anything new. But once that peak of tension subsides, he becomes more accessible, and we can work with him. That's when Ivy has the greatest chance of succeeding."* [#5]. Another stated: *"We are now dealing with interventions, bed, bath, food and after that we might be able to work with Ivy again if the entry point comes"* [#6].

Another dominant theme throughout the interviews was the importance of setting accurate expectations regarding the robot's capabilities. Multiple interviews revealed enabler 1.5 - positive initial response to the robot, as most clients were comfortable with Ivy's one-way communication style, as their primary need was expression rather than reciprocal conversation. Ivy's role as a passive listener proved sufficient for clients to experience emotional unburdening, even without receiving a response. As one care professional described, *"He doesn't need an answer, but just the part where he feels like, okay, I've let it out"* #11. However, healthcare professionals also indicated that for some clients Ivy's interactivity seemed too restricted in their impression, in some cases leading to discontinued use. This represents barrier 1.5 - a mismatch between client expectations and robot functionality turned out to be a deal-breaker for sustained use. The robot's inability to engage in two-way conversations limited its effectiveness in addressing feelings of loneliness. As one care professional noted: "*... she lost interest as she had expected Ivy to be more socially interactive"* [#17].

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Moreover, professionals emphasized the challenges of complex and unpredictable care needs (deal-breaker 1.1): *"In reality, care for clients is not so plannable as initially assessed. This makes timing of interactions extremely difficult. Especially when interaction follow up fast, when one interaction's timing goes wrong, the whole day gets out of sync"* [#5]. In contrast, facilitator 1.8, early client engagement in robot programming emerged as an enabler for sustained use. Healthcare professionals emphasized that involving clients in customizing Ivy's functionalities enhanced their sense of ownership of the robot. As one professional noted: *"We involve the clients in everything. We don't do anything without them—they lead the process"* [#3]. This collaborative approach helped ensure that the robot's capabilities aligned with specific needs and preferences of PwID. However, it is important to note that across the 19 cases, not all PwID were capable of such engagement due to cognitive limitations, highlighting the need for tailored implementation approaches.

Healthcare professional-related factors influencing sustained use of robot Ivy

Healthcare professionals' attitudes, digital competencies, and available time emerged as critical factors influencing successful robot implementation. Their ability to effectively set-up and maintain the robot, combined with their willingness to integrate it in daily care routines, and the robot's embeddedness in the care delivery, significantly impacted implementation success. The following presents some striking facilitators and barriers from **Table 5.2**, as evidenced by their frequent occurrence in successful versus discontinued cases.

The most critical barrier affecting sustained use was deal-breaker 2.1 - insufficient time for programming and adapting the robot over time. As one professional explained: *"At the beginning, I actually experienced more work instead of less, because it was mainly figuring out how to set those interactions"* [#13]. Another interviewee noted the ongoing time investment required: *"I have to plan time to be able to do that... Nothing can be done in between... It takes time to really program it well"* [#17].

Key drivers 2.1 and 2.2 - willingness to learn and adapt to new technology and the ability to program basic client interactions - emerged as essential facilitators in cases of successful implementation, as one professional noted: *"I find it really exciting to explore new things and see what's possible … I enjoy figuring out creative ways to make it work for a specific case. At first, programming was a bit tricky because I didn't have the right permissions in the system, but once that was sorted out, it became much easier. Over time, I learned the steps, and now I know exactly what to do—it just takes practice. The more you use it, the faster and easier it gets"* [#17]. However, obstacle 2.4 - inconsistent use across team members - often undermined these positive factors, stemming from varying levels of knowledge and skill or perceived lack of effectiveness of the robot. One healthcare professional notes: *"If the client does not respond to the robot or any of the robot interactions… so, there is no match or success… people (referring to colleagues) also become less motivated to use the robot and program interactions … When it is visibly successful and truly benefits the client, then the motivation is there for the staff as well, because it has a certain impact"*[#1].

Table 5.2. Client, healthcare professional, contextual and organizational related facilitators and barriers influencing the sustained use of robot Ivy

	Facilitators	Barriers
Client	**Key drivers** 1.1. Sufficient cognitive and sensory capabilities to process robot interactions 1.2. Ability to maintain attention during robot interactions 1.3. Need for structure and predictable routines 1.4. Receptiveness to neutral, consistent communication	**Deal-breakers** 1.1. Complex, unpredictable care needs requiring frequent adjustments 1.2. Inability to process or follow robot instructions independently 1.3. Strong resistance to technology adoption 1.4. Severe cognitive limitations affecting comprehension 1.5. A mismatch between a client's expectations and robot functionality 1.6. Fluctuating client well-being and health conditions affecting engagement
	Enablers 1.5. Positive initial response to the robot 1.6. Interest in and openness to the robot 1.7. Robot as a buddy, trust, confiding in and sharing with the robot 1.8. Client involvement in programming robot	**Obstacles** 1.7. Limited mobility restricting robot access 1.8. Difficulty maintaining interest over time 1.9. Need for constant staff prompting to engage with the robot
	Minor boosters 1.9. Previous experience with technology 1.10. Ability to form emotional connections with the robot	**Minor hurdles** 1.10. Initial adjustment period to the robot 1.11. Technical difficulties with touchscreen operation and interaction pace 1.12. Occasional misunderstanding of robot instructions

Table 5.2. Continued

	Facilitators	Barriers
Healthcare professional	**Key drivers** 2.1. Willingness to learn and adapt to new technology 2.2. Ability to program basic client interactions 2.3. Additional dedicated time for robot setup and adaptation 2.4. Understanding of individual client needs	**Deal-breakers** 2.1. Insufficient time for robot setup and adaptation 2.2. High staff turnover
	Enablers 2.5. Team-wide commitment to robot implementation 2.6. Regular evaluation and adjustment of robot interactions 2.7. Creativity and ability to personalize robot interactions based on client-knowledge 2.8. Adding an mobile app for the platform allows for more agile programming (in addition to the browser-based version)	**Obstacles** 2.3. Time constraints during busy shifts 2.4. Inconsistent use across team members, often caused by a lack of knowledge and skill, or a perceived lack of the robot's effectiveness 2.5. Challenges in programming complex interactions 2.6. Use of robot intervention in care not part of DNA yet
	Minor boosters 2.9. Previous experience with (healthcare) technology 2.10. Enthusiasm for innovative care solutions	**Minor hurdles** 2.7. Initial learning curve with programming interface 2.8. Need for regular updates and adjustments
Context	**Key drivers** 3.1. Clear integration with existing care routines (integral part)	**Deal-breakers** 3.1. Structural issues with connectivity and robot technology 3.2. Poor timing of implementation
	Enablers 3.2. Support from family/caregivers	**Obstacles** 3.3. Coordination challenges during holiday periods, limited capacity of staff across shifts
	Minor boosters N/A	**Minor hurdles** 3.4. Occasional technical glitches

Table 5.2. Continued

	Facilitators	Barriers
Organization	**Key drivers** 4.1. Management support for implementation • Time and training	**Deal-breakers** 4.1. Lack of organizational commitment 4.2. Diverging from implementation road-map (introducing a robot to client prior to staff training in use of robot)
	Enablers 4.2. Dedicated implementation team 4.3. Regular training opportunities 4.4. Shared learning opportunities across teams • Documentation of successful use cases	**Obstacles** 4.3. Unclear implementation responsibilities and islands (isolated initiatives) fragmented within the organization
	Minor boosters 4.5. Recognition of staff efforts in robot implementation	**Minor hurdles** N/A

Contextual factors influencing sustained use of robot Ivy

Implementation environments varied significantly across the 19 cases, encompassing differences in care settings, team dynamics, and implementation timing. These contextual elements proved crucial in determining implementation success, particularly regarding the stability of the care environment and availability of support resources. **Table 5.2** summarizes the key contextual facilitators and barriers identified across cases. Below, we elaborate on these factors.

Healthcare professionals highlighted how deal-breaker 3.2 - the timing of implementation was affected by contextual factors related to organizational challenges such as sick leave. These temporary organizational challenges were also highlighted: *"At the moment, it's extremely restless in the living room. We have a lot of sick clients and colleagues, a lot of people who have decided to leave. So, there's just a lot of unrest. A lot of unfamiliar staff that we've had to fly in, freelancers (in Dutch: ZZP'ers) because we just can't handle it ourselves anymore … And I really notice that permanent staff, such as the colleagues doing the night shift and other fixed team members, use the robot and program it for the client. But now, due to the unrest in the team, working with lots of freelancers, it's starting to be forgotten again."* [#20]. In line with this, another professional reflects on other circumstances that cause coordination challenges (obstacle 3.3): *"When Ivy arrived, a colleague of mine set it up. She also programmed the reminders for the client at that time. So, I did reach out to her and asked, 'Hey, can you help me with this?' At one point, we tried to do it over the phone because meeting in* *person wasn't possible. But the reality is, over the past few months, we've been dealing with extra workload due to a lot of staff being sick. We have a few colleagues on long-term sick leave, and there have also been vacations. So, in that sense, scheduling was also quite challenging"* [#4].

Organizational support factors influencing sustained use of robot Ivy

While this research primarily focused on micro-level implementation factors, healthcare professionals' experiences revealed that organizational support was crucial for successful implementation. Though not directly investigating organizational implementation strategies, professionals' reflections highlighted how organizational factors enabled or hindered their ability to effectively utilize the robot in client care. The following presents further context to some of the frequently occurring organizational factors from **Table 5.2**.

Our analysis revealed a hierarchy of organizational support elements. Key driver 4.1 - management support through training provision and resource allocation proved essential. Training effectiveness varied significantly across organizations. When properly implemented, training sessions combined with accessible support channels enhanced professionals' confidence and capability. As one professional noted: *"The training, the help desk. We can go anywhere with our questions. The facilities. We have a space to literally practice. And the people—I think they are easy to reach"* [#6]. These essential elements facilitate sustained use of the robot. However, inconsistent training deployment created significant barriers. This was evident in one professional's observation: *"We should have immediately trained the whole team at once in how the system works instead of me having to do it staff member by staff member"* [#1].

Resource allocation posed another crucial organizational factor. While some organizations provided dedicated implementation time (enabler 4.2), others required integration within existing workflows. As one professional described: "*I close the office door and take a moment to focus, away from the residents. Staying an extra hour after my shift just to work on the robot would actually make things much easier. Right now, I have to manage it during my shift, and just when I spend 10 minutes on it, another resident needs my attention*." [#21]. Cases that succeeded in implementation typically demonstrated strong organizational commitment, characterized by dedicated implementation teams, regular training opportunities and thorough documentation of successful use cases (enablers 4.1 - 4.3). However, findings show that deal-breakers, such as a lack of organizational commitment (4.1) and failure to adhere to the implementation roadmap (4.2), jeopardize the sustained use of the technology. In one case, where the robot was discontinued, a care professional shares: *"I wasn't there when Ivy was first introduced to us colleagues… so, I assume that a training on how the robot works could have helped. I also heard from colleagues that more people* *had the same issue. If you have to figure everything out on your own, it becomes very time-consuming, especially in a hectic period like this"* [#4].

5.4. DISCUSSION

5.4.1. Principal findings

The sustained use of social robot Ivy in 63% of cases (12 out of 19) demonstrates both the potential and challenges of integrating social robots into disability care. Building on prior research on intelligent assistive technologies in disability care (Mahmoudi Asl *et al.*, 2023; Torrado *et al.*, 2020), this study examined the value of sustained use of social robot Ivy for PwID and their healthcare professionals across 19 cases. The mixed results—where robot use continued in 12 cases but stopped in 7—highlight the complex process of adopting technology in long-term care for PwID. Our analysis revealed three key findings. First, where implementation was successful, social robot Ivy created distinct value for both clients and healthcare professionals through three key mechanisms: First, the robot's consistent and non-judgmental nature provided structure while reducing emotional burden - supporting clients' independence and wellbeing while allowing professionals to focus on meaningful interactions rather than repetitive tasks. Second, the automation of routine activities enhanced efficiency, enabling more person-centered care delivery. Third, successful implementation appeared to create a virtuous cycle where increased client independence and improved care experiences contributed to greater work satisfaction among professionals.

Second, inspired by the NASSS framework (Greenhalgh *et al.*, 2017) and Meiland's implementation model (Meiland *et al.*, 2004), our analysis categorizes barriers to sustained use according to their level of impact and complexity and distinguishes between deal-breakers, obstacles, or minor hurdles. By applying the same classification framework to facilitators as we do to barriers, we distinguish between key drivers, enablers, and minor boosters to assess their relative impact on the success of implementation. This classification emerged from analyzing both the 12 cases where robot use was sustained and the 7 cases where it was discontinued after two months.

Third, we categorized both barriers and facilitators not only by their level of impact on sustained use of the robot but also across four key domains: client characteristics, healthcare professional capabilities, contextual conditions, and organizational support. This domain-based classification allowed us to systematically examine how different factors shaped implementation success or led to discontinuation.

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5.4.2. Facilitators

The analysis revealed essential enabling factors required across all four domains for successful adaptive implementation. For clients, cognitive and sensory capabilities to process robot interactions, combined with a need for structure and predictable routines, were key drivers. This aligns with previous findings regarding the importance of matching technological capabilities to client needs in disability care (Boot *et al.*, 2018). The data showed that clients who could maintain attention during robot interactions and were receptive to neutral, consistent communication were more likely to benefit from sustained robot use.

For healthcare professionals, willingness to learn and adapt to new technology, ability to program basic client interactions, and available time for robot setup and maintenance emerged as critical factors. Using the robot, particularly its backend programming interface essential for customization, emerged as a significant challenge, requiring both time and adaptability from professionals. Adequate training, dedicated programming time, and ongoing organizational support were identified as critical factors influencing the sustained use of the technology. These findings align with recent studies (e.g., Guemghar *et al.*, 2022; Hirt *et al.*, 2021; Hung *et al.*, 2023) stressing the importance of healthcare professional engagement in successful implementation of social robots in long-term care settings, as well as research highlighting the need to optimize interfaces for all end-users, including employees (van Doorn *et al.*, 2024). Moreover, healthcare professionals consistently emphasized the importance of dedicated time for programming and ongoing adjustments to maintain effective robot use.

Contextual analysis demonstrated that clear integration with existing care routines was essential for sustained use. The data revealed that support from informal caregivers, often family members, enables successful implementation. Sustained use is jeopardized by issues related to the technology. Moreover, successful implementation depends on appropriate timing relative to staff availability. This highlights how organizational instability and high staff turnover can directly undermine technology adoption, as temporary staff lack the knowledge and commitment needed to maintain consistent robot use.

Organizational support through management commitment, dedicated implementation time, and training opportunities emerged as key drivers. Healthcare professionals specifically highlighted the importance of systematic team training and shared learning opportunities. Providing professionals with the capacity and time to engage with the technology fosters sustained use. Our findings suggest that such support shifts the perception of the robot from a burden to an opportunity to enhance care. This is especially critical in healthcare, where overstretched resources demand solutions that benefit not only clients, but also caregivers (Wottiez *et al.*, 2018). Sustained use of social robots depends on their ability to deliver value to all actors involved, including clients and caregivers (Čaić *et al.*, 2018). Particularly for social robot Ivy, whose setup and functionality heavily rely on caregiver input, organizational support is necessary to ensure it creates value for both groups.

5.4.3. Barriers

The interviews revealed distinct categories of barriers affecting implementation success. Following the classifications outlined in the NASSS framework (Greenhalgh *et al.*, 2017), barriers were classified as deal-breakers (complex), obstacles (complicated), or minor hurdles (simple). For clients, deal-breakers included complex and unpredictable care needs requiring frequent adjustments, along with severe cognitive limitations affecting comprehension. Obstacles included fluctuating health conditions affecting engagement, while minor hurdles involved technical difficulties with touchscreen operation. These findings align with previous research highlighting the importance of matching technology capabilities to client characteristics (Cobo Hurtado *et al.*, 2021). Additionally, our study underscores that beyond matching technological features (button- and text-size), factors such as the pace of interaction—how much time a client has to respond—are key in ensuring successful and sustained use, particularly for PwID with varying levels of cognitive and physical abilities.

For healthcare professionals, deal-breakers centered around insufficient time for programming and maintaining the robot, combined with high staff turnover. Obstacles included inconsistent use across team members and challenges in programming complex interactions. Minor hurdles involved initial learning curves with the programming interface. These findings echo recent studies emphasizing the need for dedicated time and resources in healthcare technology implementation (Mahmoudi Asl *et al.*, 2023).

Contextual deal-breakers included unstable connectivity and poor implementation timing, particularly during this period. Obstacles included coordination challenges during holiday periods, while minor hurdles involved occasional technical glitches. This underscores the importance of stable care environments for successful technology implementation.

At the organizational level, deal-breakers included lack of systematic support and divergence from implementation roadmaps. Obstacles included unclear implementation responsibilities and fragmented initiatives within organizations. In line with recent research, this highlights the critical role of organizational commitment and structured implementation approaches in achieving sustained use of social robots in care settings (Mahr *et al.*, 2024).

5.4.4. Synthesis of findings

While this study identifies factors influencing sustained use across the client, professional, contextual, and organizational domains, the observed interdependencies between these four domains underscore that they cannot be viewed in isolation. Instead, they form an interconnected system in which the interplay between *organizational* and *individual resources*—contingent on contextual *factors*—determines implementation success.

For example, when strong management support is present—offering time and training at the meso level—and healthcare professionals demonstrate a willingness to learn and adapt to new robotic technology at the micro level, we observe an enhanced ability to personalize robot interactions for clients. In contrast, when organizational resource constraints were evident—such as insufficient support for deployment and a lack of management commitment—these limitations often coincided with a lack of dedicated time for healthcare professionals, hindering their ability to properly learn and program robot interactions. However, in such cases, healthcare professionals often relied more on individual resources, such as their commitment to quality of care, willingness to invest extra effort, and focus on personal client needs. Notably, this personal dedication was evident in professionals who sought creative ways to utilize the robot despite resource limitations.

Beyond healthcare professionals, clients themselves also leveraged their resources to support the sustained use of the service robot Ivy. In some cases, clients engaged in programming and customizing the robot through co-creation with healthcare professionals. These client contributions complemented both organizational and individual professional resources, enhancing the likelihood of successful implementation.

Moreover, the context in which robots were implemented significantly influenced both organizational and individual resources. Contextual challenges, such as high employee turnover or increased sick leave, placed additional strain on organizational resources, which, in turn, reduced healthcare professionals' ability to dedicate time and energy to robot implementation. This interdependence calls for an implementation approach that recognizes both available organizational resources and individual resources within the given context, ensuring not only adequate support for healthcare professionals' dedication to delivering personalized, technology-assisted care but also enabling clients to leverage their own resources based on their capabilities and needs.

5.4.5. Limitations and Strengths of the Study

Several limitations of this study should be considered. First, our analysis relies primarily on healthcare professional perspectives, as client interviews across all 19 cases were not feasible due to cognitive limitations. Second, although our study investigates adaptive innovation during the execution and continuation phases of early adoption, the two-month implementation period captures only initial adoption and early use, not long-term sustainability.

The strength of this study lies in its analysis of 19 cases across 6 different care organizations, encompassing both sustained use and discontinuation, which provided rich comparative insights. The inclusion of both successful and discontinued cases allowed for a nuanced understanding of facilitators and barriers across multiple care settings. Unlike much of the existing body of literature, which primarily consists of scoping/systematic reviews (Krick *et al.*, 2019; Mahmoudi Asl *et al.*, 2022; Robinson *et al.*, 2019; Scoglio *et al.*, 2019); and lab or controlled studies (Boumans *et al.*, 2020; Rossi *et al.*, 2022), this field study investigated adaptive robot implementation in 19 actual productive care environments over a duration of 2 months. This approach offered a unique opportunity to explore long-term real-world experiences that go beyond an early pilot phase (Huijnen *et al.*, 2021; Blindheim *et al.*, 2022) and hypothetical or controlled scenarios (Boumans *et al.*, 2020; Rossi *et al.*, 2022). Field studies in this area and at this scale are scarce, especially those examining the execution and continuation phases of adaptive innovation. By investigating 19 unique cases of robot deployment rather than focusing on a single robot, this research provides particularly valuable insights. Furthermore, the use of established theoretical frameworks (the NASSS framework and Meiland's implementation model) ensured a structured and complete analysis of the value of sustained use and related facilitators and barriers.

5.4.6. Scientific, Clinical, and Societal Relevance of the Study

This study makes several important contributions to the field. First, it provides a novel analysis of sustained versus abandoned use of social robots within the adopter system domain, focusing on value for the two key end-user groups: PwID and professional caregivers in real-world care settings. The findings present user value of the technology, including improved daily structure, greater independence, and enhanced emotional well-being for PwID, and support for healthcare professionals in delivering efficient, person-centered care. Second, it presents classifications of facilitators and barriers across four critical domains: client characteristics, healthcare professional capabilities, contextual conditions, and organizational support. These findings advance both research and practice by offering concrete implementation guidance while illuminating crucial prerequisites for successful robot deployment in disability care at both the micro-level, focusing on end-users, and the meso-level, addressing organizational factors.

By examining the execution and continuation phases of implementation (Meiland *et al.*, 2004), rather than early-stage preconditions and preparation, this study provides unique insights based on actual user experiences over a two-month period. The findings reveal how social robots can create distinct value: enhancing mental and social health for people with intellectual disabilities and complex needs while simultaneously reducing workload and improving care delivery efficiency for healthcare professionals.

This dual focus on value creation and implementation factors is particularly significant given projected global healthcare worker shortages (WHO, 2024). While previous research on intelligent assistive technologies has primarily emphasized client benefits (Torrado *et al.*, 2020), our findings demonstrate that successful implementation requires creating value for both end-user groups. Intelligent assistive technologies (IAT) can effectively address workforce challenges and meet the growing demands for disability care services only when they meaningfully support both clients and caregivers, and when implementation factors for both groups are adequately considered. By studying implementation in real-world care environments with their inherent staffing pressures and organizational dynamics, our research offers high external validity regarding the dual value creation needed for both clients and caregivers. The classifications of facilitators and barriers across four domains provide organizations with concrete guidance for identifying and addressing critical implementation factors for both end-user groups.

5.4.7. Implications for practice

Our findings provide several practical implications for long-term care organizations implementing social robots for PwID. Firstly, careful client selection is crucial. Organizations should focus on individuals with sufficient cognitive capabilities and predictable care needs to ensure meaningful and effective interactions with social robots. Secondly, healthcare professionals must be provided with dedicated time and resources to manage robot programming and maintenance. Without these, the integration of such technology into care routines may face significant challenges. Thirdly, the timing of implementation must take into account both staff availability and client wellbeing. Properly aligning these factors can help avoid non-adoption or disruptions of robot use. Findings show that social robot Ivy can contribute to well-being, while a certain threshold of client well-being is required to accept the robot in the first place. Fourthly, organizations should deliver systematic training and support to entire care teams. This ensures that all staff members are equipped with the knowledge and skills needed to prevent disruptions of maintenance and frequency of use, thereby maximizing the value of social robot use. Finally, regular evaluation and adjustment of robot interactions are essential for sustained use. Continuous monitoring and fine-tuning help maintain engagement and ensure that the robots continue to meet the evolving needs of both clients and staff. These practical implications can guide organizations in creating optimal conditions for successful robot implementation in long-term care settings.

5.4.8. Recommendations for Future Studies

Continued research is needed in three key areas. First, longitudinal studies beyond the initial 2-month implementation period should evaluate sustained robot use and integration into care practices. Second, mixed-methods studies combining direct client assessments with quantitative interaction data would provide more comprehensive insights into robot usability and impact. Future work incorporating direct client feedback could provide a more complete evaluation. Essential metrics should include frequency of use, types of interactions, and objective measures of client engagement. Third, participatory design studies involving clients, care professionals and technologists are needed to systematically improve both the robot's client interface and the professional programming platform. Additionally, studies investigating organizational implementation strategies can shed light on how to optimize social robot integration at scale. In the current study, we interviewed healthcare professionals that are directly involved in client care, resulting in a strong focus on micro-level factors related to clients, employees, and the specific context of implementation. Nonetheless, our findings also highlight organizational insights, suggesting that dedicated implementation teams and streamlined training programs may enhance the sustained use of service robots across diverse care environments. Future meso-level research should examine managerial strategies and organizational activities that enable healthcare professionals to seamlessly integrate social robots into existing care routines.

5.4.9. Conclusion

Building on growing evidence supporting the potential of social robots in disability care (Boot *et al.*, 2018; Guemghar *et al.*, 2022; Huijnen *et al.*, 2021), this study demonstrates that sustained use of social robot Ivy can create value for both PwID and healthcare professionals when implemented under appropriate conditions. Success requires careful attention to user needs and preferences, client characteristics, healthcare professional capabilities, contextual factors, and organizational support. The classifications of facilitators and barriers provide structured guidance for healthcare organizations implementing social robots for people with intellectual disabilities.

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CHAPTER 6

SERVICE ROBOTS AND INNOVATION: AN ECOSYSTEM APPROACH

In the case of this chapter:
Mahr, D., Odekerken-Schröder, G., & **Steins, M.** (2024). Service robots and innovation: An ecosystem approach. *Journal of Product Innovation Management.*

6.1. INTRODUCTION

The proliferation of service robots has brought about innovation that provides value across various industries. These robots, distinguished by their autonomous and adaptable interfaces, engage in diverse interactions with users and other stakeholders (Čaić *et al.*, 2019; Wirtz *et al.*, 2018). With a certain degree of autonomy (Onnasch & Roesler, 2021), service robots with a physical embodiment navigate relatively unstructured operational environments, setting them apart from industrial robots. Typical examples include service robots providing patient care in the healthcare sector, facilitating goods delivery in transportation, serving orders to guests in the in the hospitality industry, and monitoring sites in the security sector (Čaić *et al.*, 2018; Simoni *et al.*, 2020; Steins *et al.*, 2024; Lin *et al.*, 2011). The global deployment of service robots has seen a robust annual growth rate of 13% from 2020 to 2022 (International Robotics Federation, 2023). This growth is particularly notable in the hospitality sector, which experienced an 85% increase in robot sales in 2021, and in healthcare, where there was a 23% rise in robots for rehabilitation, therapy, and assisted living. While service robots become more accessible, technologically advanced, and supported by innovative operational models like robots-as-a-service (Buerkle *et al.*, 2023; Chen and Hu, 2013), they also face challenges in creating value. Among other issues, innovation managers across industries seek guidance on setting up and managing complex ecosystems, navigating autonomous human-robot interactions in unstructured environments, and selecting from various physical appearances, aesthetics, and tasks. These examples illustrate some of the challenges service robots pose for value creation.

A large body of literature in robotics and information science focuses on advancing the technological capabilities and physical functionalities of service robots (e.g., Pyo *et al.*, 2015). Simultaneously, research in fields like services (Jörling *et al.*, 2019), marketing (Mende *et al.*, 2019), and human-computer interaction (Tay *et al.*, 2014) has concentrated on various aspects of service robot deployment. This literature argues that innovative solutions based on service robots can provide value through their functional and social capacities (Čaić *et al.*, 2018; Schepers and Streukens, 2022). However, the deployment of increasingly capable service robots requires not just designing user-robot interactions but also a holistic approach to innovation management that transcends organizational boundaries and involves various societal stakeholders.

It is worth noting, however, that the realm of service robots and their impact on innovation remains limited in major innovation journals. Existing literature on service innovation (e.g., Engen and Magnusson, 2018) underscores the crucial role of frontline employees (FLEs) involving human-robot interaction at the micro level. Given that service robots are increasingly becoming the focal point of ecosystems, research can benefit from a focused exploration of innovation employing service robots, which present new challenges due to their autonomous nature and reliance on a broader ecosystem. Successful innovation management needs to align the needs and leverage the expertise of various stakeholders, such as users, technology providers, frontline personnel, service providers, and policymakers. The involvement of multiple stakeholders at the micro (user), meso (organizational), and macro (societal) levels is a crucial characteristic of the innovation ecosystem. These stakeholders have to work collaboratively to generate value by developing and implementing innovations (Dedehayir *et al.*, 2022).

The current article unpacks the potential of service robots to foster innovation and examines how the underlying ecosystem contributes to value creation. In this pursuit, we explore the paradigm of Public Value Innovation (PVI) as an alternative approach to conventional market-driven innovation, particularly suited for complex societal issues (Spanjol *et al.*, 2024). Our study highlights that innovation involving service robots requires a collective perspective, wherein value emerges from the interplay between private and public sectors, tackling grand societal challenges (GSCs) such as healthcare, education, digitalization, and security (Mazzucato and Ryan-Collins, 2022). This study aims to make the following theoretical contributions to innovation management.

Firstly, the research proposes a comprehensive conceptualization of service robots, identifying key characteristics that determine innovation management. This novel perspective enriches the nascent discourse on service robots within the innovation literature. It emphasizes distinct characteristics such as autonomy, aesthetics, assistive roles, and user interfaces of service robots, and uses these characteristics to outline various types of service robots. This study goes beyond the current state-of-the-art literature, which provides insights into the organizational and user benefits of service robots, by exploring how the characteristics of service robots impact innovation management practices and value creation. More specifically, we identify service robots' degree of autonomy and ecosystem integration as two orthogonal determinants of innovation management, providing new insights into technology innovation (Pyo *et al.*, 2015) and ecosystem literature (Adner, 2017). Secondly, through both conceptual and empirical development, this research underscores the role of service robot-specific technologies and the development of an ecosystem in different stages, driving innovation. An ecosystem-as-structure approach delineates the alignment of the stakeholders engaged on micro, meso, and macro levels of the ecosystem and the shared value proposition (Adner, 2017). Our research explores the long-term perspective of ecosystem development demanding careful management of the different stakeholders' roles and activities as well as their inherent change throughout the different phases of ecosystem development. Thirdly, our research extends the emerging framework of innovation for Public Value by exploring how deploying service robots can effectively tackle the complexities and value-laden dimensions inherent in societal challenges (Mazzucato and Ryan-Collins, 2022). Our illustrative case of service robots and the innovation practices aiming at user-centric, high-quality, affordable, and accessible long-term care explores the collaborative value creation of public and private stakeholders. This research extends the existing literature on service robots, Public Value, and ecosystem dynamics in innovation management, culminating in a comprehensive research agenda combining these domains.

6.2. CONCEPTUAL DEVELOPMENT

This section develops the conceptual foundations of service robots in innovation, particularly their role in advancing Public Value Innovation (PVI). Specifically, we define Service Robot-based Innovation, discuss key characteristics that determine innovation management, and present a comprehensive overview of current service robot deployment. The initial focus on outlining the definitions and characteristics is essential to understand service robots in the context of innovation. We proceed by introducing Service Robot-based Innovation for Public Value, where ecosystems of public and private stakeholders converge in creating Public Value. Subsequently, we extend the standalone technology perspective on service robots by considering the integration of service robots in broader ecosystems. We theorize that an ecosystem enabling innovation for Public Value hinges on the service robot's autonomy and system integration, and we thoroughly examine the types, actors, and levels of our ecosystem conceptualization.

6.2.1. Service Robots for Innovation

The exploration of service robots and their role in innovation remains largely underexplored in major innovation journals, like the Journal of Product Innovation Management. An exception is the study by Lee and Coughlin (2015), which investigates technology adoption by older adults and briefly touches upon social robots in the light of technology uptake. This conceptual development section draws upon research from marketing, design, human-computer interaction, and robotics to conceptualize innovation involving service robots. *Definition of Service Robots.* Service robots, as system-based autonomous, physically embodied, and adaptable interfaces, engage in interactions, communication, and service delivery to various stakeholders, including customers, employees, or other service robots (De Keyser and Kunz, 2022; Odekerken-Schröder *et al.*, 2022; Wirtz *et al.*, 2018). This encompassing definition of service robots underscores their capacity to execute a broad spectrum of tasks, spanning both physical and non-physical domains while operating with a high level of autonomy (Jörling *et al.*, 2019) and placing significant emphasis on human-robot interaction (Onnasch and Roesler, 2021). By focusing exclusively on robots with a physical form, this research investigates how these tangible interfaces are implemented within service environments. Embodiment and presence in the same physical space as the user (e.g., the service frontline) enables these service robots to have direct human-robot-interactions (van Doorn *et al.*, 2017) and provide service in every day, often unstructured operational environments, which differentiates them from chatbots and other virtual AI interfaces (Jörling *et al.*, 2019).

Service robots set themselves apart from industrial or field robotics by assisting with everyday human activities (Kawamura *et al.*, 1996). Thus, service robots frequently collaborate with FLEs and engage directly with customers (Phillips *et al.*, 2023). When implementing service robots, the involvement of various stakeholders, such as the FLE, is crucial to maximizing both human and technological strengths (Noble *et al.*, 2022).

Service Robot-based Innovation. We view Service Robot-based Innovation as the ecosystem-enabled development and employment of such autonomous, adaptable, embodied and interactive interfaces that create value for individuals, organizations, and society at large. While innovation in service robots often stems from technical advancements and features, Service Robot-based Innovation emphasizes value creation through novelty and relevance for the various stakeholders within its use context, especially in comparison to alternative solutions. This perspective highlights the roles of these robots within service settings, shifting the emphasis from their design to the services they provide and the role of the stakeholders in the broader ecosystem (Raff *et al.*, 2020). Moving beyond viewing service robots as standalone smart products, our definition underscores the importance of their effective integration into service contexts, demanding different organizational innovation management practices. In the following, we examine key characteristics of service robots and their relation to these practices.

Characteristics of Service Robots. Early research on service robots already demonstrates that to drive innovation and transition service robots from research laboratories to widespread adoption, the development of service robots should prioritize the seamless delivery of valuable services, requiring minimal user intervention, all while maintaining cost-effectiveness (Kawamura *et al.*, 1996). In synthesizing key insights from the field of service and social robotics, we review core robot design characteristics identified by Čaić *et al.* (2019) - *autonomy, assistive role, and morphology* - with salient criteria highlighted by Belanche *et al.* (2020), which include *aesthetics, manipulability,* and *proactivity*. More specifically, we include proactivity as a component of autonomy, morphology as an aspect of aesthetics, and manipulability as defining the user interface. By delineating these characteristics, we enable a deeper theoretical exploration of how service robot design influences innovation management practices in the direct service environment and broader ecosystem (Raff *et al.*, 2020).

Autonomy. A service robot's autonomy refers to the degree to which robots are capable of making decisions and operating without constant human intervention (Lee *et al.*, 2016). In a restaurant setting, delivery robots operate autonomously in a relatively structured environment without constant human intervention (Odekerken *et al.*, 2022; Schepers *et al.*, 2022). The concept of autonomy of service robots offers interesting angles for innovation management, particularly when considering their potential for task substitution and augmentation (De Keyser and Kunz, 2022). Implementing (semi-)autonomous service robots necessitates organizational adjustments in frontline roles and workforce engagement, emphasizing the importance of human skills in conjunction with robots that either substitute or augment human capabilities. Developing highly autonomous robots typically requires service providers to collaborate with technology developers, service designers who oversee implementation, and research institutes specializing in advanced AI research (Lu *et al.*, 2020). Additionally, innovation capabilities may need to encompass considerations of AI ethics to ensure the responsible and sustainable use of these technologies (Akter *et al.*, 2023). Building upon the foundation of autonomy is proactivity in service robots. It involves the robot's capacity to initiate interactions and provide anticipatory assistance (Belanche *et al.*, 2020), beyond performing tasks independently in environments such as restaurants. Proactive service robots may actively initiate communication and offer help, reflecting proactive behaviors similar to those of human service employees (Rioux and Penner, 2001; Garrell *et al.*, 2017). Therefore, proactivity, as a function of autonomy, prompts innovation teams to explore new avenues of customer engagement that supplement traditional human-to-human interactions. For example, a proactive service robot in a bookstore might analyze a customer's browsing pattern to recommend books in the same genre or by similar authors, leveraging advanced algorithms for real-time data analysis and customer preference prediction. This ensures that the robot's suggestions are both relevant and enhance the shopping experience, a significant shift from traditional, reactive customer service interactions.

Aesthetics. Focusing our investigation on service robots, the aesthetics of such robots is of key importance as it significantly influences user interactions with those robots (Belanche *et al.*, 2020). Aesthetics encompasses not only the physical form but also the appearance of service robots, also referred to as *morphology* (Čaić *et al.*, 2019). Morphology deals with the range of physical appearance of service robots, from machine-like to human-like or even animal-like designs, significantly influencing user interactions (Fong *et al.*, 2003). An illustrative example is the therapeutic robot PARO, designed as a seal, demonstrating the influence of morphology in practice (Lee and Coughlin, 2015; Pfadenhauer and Dukat, 2015). By aligning a robot's appearance (e.g., seal) with its intended functions (e.g., comforting therapeutic use), organizations can effectively meet the diverse needs of different stakeholders, such as customers and employees (Li *et al.*, 2010). Notably, prior research in robotics has mainly emphasized aesthetics and physical form, underpinning the hypothesis that a robot's human-like appearance leads to higher user acceptance (Walters *et al.*, 2008) or use intention (Blut *et al.*, 2021).

Assistive role. The service robot's assistive role implies that the service robot can fulfill specific roles, providing assistance ranging from physical tasks to emotional and cognitive support (Jörling *et al.*, 2019). To understand the service robot's role in the innovation process, we make a broad categorization based on a service robot's assistive role, distinguishing between functional service robots and social service robots. *Functional service robots* are primarily task-oriented, designed to perform specific functions autonomously. Their interactions with humans are mainly transactional, like a hospitality robot showing guests to their table (Schepers and Streukens, 2022). *Social service robots* focus on emotional and social roles and engage with humans in social settings, such as robots that accompany elderly residents in care facilities. These robots are programmed to interact with humans in a friendly and approachable manner, providing company or entertainment (Čaić *et al.*, 2018). The assistive role of service robots necessitates a balance between the mechanistic aspects of task-oriented robots and social robots' more organic, interactive nature. Service designers within organizations should ensure that balance to facilitate creativity, learning, and interaction in both human and robotic collaborations (Tidd and Bessant, 2020). For example, in a healthcare facility, functional service robots are used for precise tasks like medication delivery, requiring a structured integration approach across different stakeholders. Simultaneously, social robots offer patients emotional support, necessitating a flexible, interactive approach. The organization's innovation management must adeptly balance these two, ensuring efficient task completion for predominantly functional robots, while fostering empathetic human-robot interactions for social robots, ultimately enhancing patient care and staff collaboration.

User interface. The final design criteria, service robots' user interface includes hardware and software that facilitate human-robot interaction, such as touchscreens, voice recognition, and other tactile feedback mechanisms such as gesture recognition (Fong *et al.*, 2003). Central to interactions with service robots is the user interface's *manipulability* (Belanche *et al.*, 2020). It focuses on the degree to which users can customize and tailor their service experience by directly influencing the robot's actions according to personal preferences or desired types of contact (Van Doorn *et al.*, 2017; Jörling *et al.*, 2019). This implies a more active role for users in value co-creation (Mahr *et al.*, 2014), as greater manipulability allows for more personalized interactions (Jussila *et al.*, 2015). In service contexts, the user interface of the physical service robot might be complemented with an additional interface and application for the worker, who can access the service robot resources through a web-based interface on their smartphone or laptop (van Doorn *et al.*, 2023). To enhance manipulability, service designers and product developers can design a variety of interaction modes with the robot, such as verbal communication, movement, tactile engagement, or interactive displays. Facilitating user-driven customization of robot actions promotes value co-creation by catering to individual needs and preferences (Čaić *et al.*, 2018). Emphasizing manipulability requires a thorough understanding of user preferences and the incorporation of adaptable, user-focused design principles in robotic technologies (Tidd and Bessant, 2020). Innovation managers are thus tasked with identifying which service experience aspects can be modified through robot use, ensuring that the level of manipulability meets user expectations and enhances the overall service experience (De Keyser and Kunz, 2022). Where proactivity aims at enhancing user experiences through proactive service robot behaviors, manipulability of these robots allows for user influence over the experience, thereby bridging the gap between robot-led and user-driven service experiences.

6.2.2. Types of Service Robots in Research and Practice

This section provides an in-depth exploration of service robot types, highlighting their key characteristics as discussed in the previous section, and assessing their influence on Service Robot-based Innovation in practice. Each type represents a specific application of robotics, tailored to meet the needs and challenges of different stakeholders in their respective contexts.

Table 6.1 provides an overview of service robots widely employed in practice and studied in existing research. This overview aims to concretize the characteristics, revealing considerable variance among types of robots in their levels of autonomy, assistive role, aesthetics, and user interface. These factors are crucial as they significantly influence different stakeholders involved in Service Robot-based Innovation.

Table 6.1. Overview of service robot types

Type	Reference	Context	Autonomy	Aesthetics	Assistive Role	User interface
Delivery robot 	Odekerken-Schröder *et al.* (2022) Schepers *et al.* (2022)	Hospitality - Restaurant	*Low - Medium* Semi-autonomous, programmed and instructed by humans *Proactivity*: low. Potential for programmed greeting and seating.	Humanoid with varying human-like features.	Functional and limited social tasks; human-like robots for drink delivery and interaction, machine-like for dish delivery.	Touchscreen, limited human-like voice communication. *Manipulability*: low. Limited for customers, FLEs customize their experience by deciding on if and how to use the robot in serving customers.
Kiosk - reception-customer service robot 	Leung (2022) Reis *et al.* (2020) van Pinxteren *et al.* (2019)	General public service	*Medium* Can autonomously execute decisions from integrated data. *Proactivity*: medium. Initiates interactions based on sensor detection.	Humanoid robot with human-like appearance and features.	Performs social, functional i.e. informational tasks. Welcoming, providing directions, check-ins; informational tasks.	Combination of voice-based and touchscreen. *Manipulability*: medium. Customization of service experience by choosing from multiple services offered.
Retail robot 	Brengman *et al.* (2021) Song and Kim (2022)	Retail	*Medium* Can autonomously execute decisions from integrated data. *Proactivity*: medium. Initiates interactions based on sensor detection.	Humanoid robot with human-like appearance and features.	Functional. Assist with inventory management, customer guidance, and even direct sales.	Combination of voice-based and touchscreen. *Manipulability*: medium. Customization of service experience by choosing from multiple services offered.

Table 6.1. Continued

Type	Reference	Context	Autonomy	Aesthetics	Assistive Role	User interface
Companion robot 	Odekerken-Schröder *et al.* (2020)	Domestic-private use	*Low - Medium* Pre-set interactions like reminders or weather updates, combined with programmed autonomous behavior, such as "independent" exploration, reaction to sound and changes. *Proactivity*: high. Recognizes human presence and initiates interactions.	Animal-like form combined with a robot-like voice.	Predominantly social, offering companionship. Social and emotional support, various tasks like reminders, photography.	User interface is voice-based. *Manipulability*: high. Customization by choosing from multiple services offered.
Patient Assistant Robot 	Čaić *et al.* (2019) Heerink *et al.* (2008) *Current study*	Elderly-Healthcare	*Low* Executes pre-programmed tasks, no independent decision-making. *Proactivity*: low-medium. Scripted interactions with perceived proactivity from client point of view.	Range from animal-like to humanoid and unique designs.	Predominantly social. Social support, cognitive assistance, basic task reminders.	Mostly human-like voice-based, some with touch screen. *Manipulability*: medium. Users can customize their service experience and choose from multiple services offered.

Table 6.1. Continued

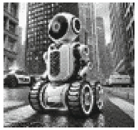
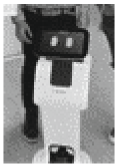
Type	Reference	Context	Autonomy	Aesthetics	Assistive Role	User interface
Security / Police Robot 	Chen *et al.* (2020) Lin *et al.* (2011) McGuire (2020)	Public Spaces (e.g. parking, malls, hospitals)	*Medium* Autonomous with teleoperation for complex scenarios. *Proactivity*: low. Reactive to specific tasks.	Machine-like, partial human voice features.	Functional. Functional tasks like surveillance, patrol, and alerting	Voice-based, screen for instructions, teleoperation and human-to-human interaction. *Manipulability*: low. Formal communication during programmed to perform surveillance and patrol tasks. Users cannot manipulate these services.
Education Robot 	Buchem (2023) Buchem and Baecker (2022) Har and Ma (2023)	Schools, Corporate trainings	*High* AI-driven, conversational, content-specific training. *Proactivity*: medium. Recognizes human presence and initiates interactions.	Machine-like, vaguely human posture.	Social and functional. Educational support, social and informational tasks.	Voice-based, touchscreen, web-based for development. *Manipulability*: high. Users can customize their service experience.
Telepresence robot 	Han and Conti (2020) Niemelä *et al.* (2019) Rae *et al.* (2014)	Workspa-ces Education Care-settings	*Low* Telepresence, remote operation, limited automation. *Proactivity*: low. User-controlled actions.	Machine-like, adjustable height.	Functional. Facilitates remote interactions, user-controlled movement.	PC (browser)-based, remote control options. *Manipulability*: medium. Users can customize their service experience by remotely navigating the telepresence robot.

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Table 6.1. Continued

Type	Reference	Context	Autonomy	Aesthetics	Assistive Role	User interface
Robot for unsafe/ unpleasant task 	Fankhauser *et al.* (2018) Reddy *et al.* (2015) Tamura *et al.* (2020)	Mines, Fires, Earth-quakes	*Low* Entirely remote-controlled for precision. *Proactivity*: Low. User fully controls the robot.	Machine-like	Functional Performs tasks in hazardous environments.	PC (browser)-based, operated via a gaming controller. *Manipulability*: medium. User remotely controls the robot.
Autonomous "Last-Mile" Delivery Robots 	Imad *et al.* (2022) Pani *et al.* (2020)	"Last-mile" delivery (food and parcel)	*High* AI for navigation, coordination between warehouses, retailers, customers. Operator control in certain cases. *Proactivity*: Low. Robot delivers orders and does not really proactively engage in service interactions.	Machine-like	Functional. Robot performs "Last mile" delivery	PC-based. *Manipulability*: Low. No manipulability for customers.

6.2.3. Service Robot-based Innovation for Public Value

Addressing grand societal challenges requires the concerted efforts of civil society and public and private institutions towards innovative ways, including integrating Service Robot-based Innovations (George *et al.*, 2016; Moore, 2013). Public Value Innovation (PVI) has emerged as a distinct paradigm, providing an alternative to traditional market-driven innovation. Typically, in cases of positive externalities such as free education for all or mass vaccination to control a pandemic, market-driven solutions are not readily available. This evolving theory of Public Value is grounded in a collective perspective, suggesting that value is co-created through interactions between the private and public sectors, rather than solely generated by the former and subsequently regulated by the latter (Mazzucato and Ryan-Collins, 2022). In the context of service robots, innovation for Public Value encompasses the conception, development, and realization of products and services that employ service robots and involve collaborative efforts among public and private actors to pursue societal goals (Mazzucato and Ryan-Collins, 2022; Spanjol *et al.*, 2024). It contrasts with a market-driven paradigm, which predominantly emphasizes market value creation by private stakeholders. Unlike social or responsible innovation, which concentrates on governing and evaluating innovations for their potential negative impacts and benefits to societal challenges (Voegtlin *et al.*, 2022; Spanjol *et al.*, 2024), PVI focuses on the public sector as the primary catalyst, providing direction, structure, and resources (Stilgoe *et al.*, 2013). Ecosystems of stakeholders converge in creating Public Value, introducing innovative models and strategies to enhance collaboration (Carayannis *et al.*, 2012). Enriching the emerging foundations of PVI, the following section delves into ecosystems in innovation management and their essential role for collaboration between public and private stakeholders to achieve collective goals.

6.2.4. Ecosystems for Service Robot-based Innovation

Within the academic discourse, various perspectives on ecosystems exist, each offering unique insights into the dynamics of innovation management. Three prominent perspectives include ecosystem-as-co-evolution, ecosystem-as-affiliation, and ecosystem-as-structure. The first perspective, ecosystem-as-co-evolution, emphasizes the dynamic interplay of stakeholders engaging in open exchanges with their environment (Teece, 2007; Hou and Shi, 2021). The second perspective, ecosystem-as-affiliation, is characterized by intricate networks shaping the configuration of stakeholders (Adner, 2017). The third perspective, ecosystem-as-structure, concerns the organization of activities defined by their underlying value proposition. Jacobides *et al.* (2018) contend that an innovation ecosystem revolves around a novel value proposition. In our illustrative case, where the goal is to achieve user-centric, affordable, accessible, and high-quality long-term care solutions, we align our presentation with the ecosystem-as-structure perspective. According to Adner (2017), an ecosystem-as-structure is defined as "the alignment structure of the multilateral set of *stakeholders* that need to interact in order for a focal value proposition to materialize" (p. 42).

Understanding Ecosystem-as-Structure

When considering the engagement of different stakeholders to contribute to this value proposition in an innovation ecosystem, strategic decisions regarding who to collaborate with, at which development stage of the ecosystem, how to engage them, and when to initiate partnerships are crucial. Studies on stakeholder management and open innovation highlight four critical strategic decisions: (1) determining the breadth of the stakeholder network, (2) selecting the type of integrated stakeholders, (3) ensuring the quality of organizational engagement, and (4) recognizing the significance of timing in stakeholder integration (Juntunen *et al.* 2019).

When these strategic decisions about the stakeholders have been made, an innovation ecosystem strives for an aligned value proposition that can be described along four definitional components of the 'ecosystem-as-structure'. First, the alignment structure entails a mutual agreement among stakeholders regarding their positions and the flow of activities within the ecosystem. Second, the multilateral aspect emphasizes interactions extending beyond bilateral relationships, highlighting the centrality of engagements across multiple relationships. Third, the set of stakeholders collaboratively formulate the value proposition, each contributing unique elements to this collective effort. Finally, the realization of the envisaged benefits for the target audience marks the materialization of the value proposition (Adner, 2017).

Collaboration mechanisms within innovation ecosystems support the alignment around a collective value proposition. To begin with, coordination, as outlined by Ritala (2023), involves effectively managing complementary elements through suitable technologies, regulations, and norms within a platform, resulting in a unified value proposition (Jacobides *et al.*, 2018). Collective action, a crucial component in realizing the value proposition, is characterized by collaborative efforts from diverse groups of people or organizations. The persistent and complex nature of the value proposition necessitates ongoing experimentation and engagement by multiple groups, rather than individual entities, to effectively confront the inherent complexities (Albareda and Sison, 2020). Finally, generativity, defined as the extent to which technical and social elements interact to enable creativity, innovation, and alternative solutions (Yoo *et al.*, 2012), further enriches the understanding of organizational dynamics within innovation ecosystems. The following sections discuss Service Robot-based Innovation and stakeholder roles in multi-level innovation ecosystems.

Service-Robot Innovation across Ecosystem Levels

The use of service robots is closely intertwined with various levels of the ecosystem, each influencing innovation management and value creation within organizations and their collaborations (Appio *et al.* 2021). Designing Service Robot-based Innovations necessitates effective teamwork among diverse stakeholders across micro (user), meso (organizational), and macro (societal) levels (Tidd and Bessant, 2020).

The Micro Level. We define the micro or the local level as the triad around the user. In this case, the micro level consists of the following stakeholders involved in a triad around the robot: client, formal caregivers (e.g., nurses and other care professionals), and informal caregivers (e.g., friends and relatives; Odekerken-Schröder *et al.* 2022). At the micro level, the use of service robots will remarkably change customer experiences. They offer consistent and error-free service interactions without human errors and fatigue (Huang and Rust, 2018). However, their integration necessitates human employees to adapt and learn effective collaboration with these automated counterparts (Huang and Rust, 2022; Paluch *et al.*, 2022). More specifically, organizations should ask themselves what assistive roles the service robot will perform (Čaić *et al.*, 2019), which is contingent on customer features (e.g., technology readiness, personality traits) and the nature of the service encounter (Belanche *et al.*, 2020). For example, customers might differ in their relational orientations (van Doorn *et al.*, 2017) or involvement level (Belanche *et al.*, 2020) which most likely influences their acceptance of service robots at the micro level.

The Meso Level. We define the meso level as the organization in which multiple micro levels are nested. The key stakeholders at the meso level are the different organizations (i.e., long-term care providers) that implement a service robot for multiple use cases. Organizations face a staffing challenge in these labor-intensive sectors and explore to what extent service robots can substitute or augment human staff (De Keyser *et al.* 2019). These robots present a promising avenue to enhance organizational competitiveness by delivering cost-effective, efficient, and reliable services. For effective deployment and operation of service robots in the micro-environment where actual service delivery occurs, organizations must ensure readiness at the meso level, also referred to as the cross-functional level (Tidd and Bessant, 2020). This includes establishing robust ICT infrastructure and engaging legal and GDPR departments to navigate compliance and data protection requirements (Söderlund, 2023).

The Macro Level. However, the impact of service robots extends beyond individual organizations to a network of different stakeholders (i.e., health insurance, technology provider, long-term care providers, and research institutes), which we define as the macro level (societal level). Effective ecosystems are characterized by a seamless interplay of the value contributors that fuel innovation for Public Value (Han *et al.*, 2022). Introducing service robots demands collaborative efforts from different stakeholders within the ecosystem, fostering productivity, resource efficiency, safety, and innovation.

To summarize, service robots emerge as important assets in modern, thriving ecosystems, capable of collaborating harmoniously with humans, offering data-driven insights, and holding the potential to elevate overall service quality. Given our conceptualization of service robots, the degree of autonomy in these robots is identified as the key characteristic affecting innovation management practices, as it enables the development of flexible service solutions that can adapt to diverse user needs without human intervention. Autonomy is distinct from the characteristics aesthetics, assistive roles, or user interface because it enhances the potential for proactive and independent service delivery by robots, but also influences the strategic direction of organizations deploying these robots. More specifically, varying levels of the service robot's autonomy require collaboration within and between all ecosystem levels to integrate stakeholders with diverse perspectives, expertise, and resources. Consequently, autonomy and ecosystem integration become critical in approaching innovation management around service robot employment, as both underscore the complexity of human-robot interactions and the involvement of all ecosystem levels.

Table 6.2 maps the deployment of service robots along the dimensions of autonomy and integration into the ecosystem and describes value creation across the ecosystem levels.

- Service robots exhibit varying levels of *autonomy*, capable of decision-making and operation with or without continuous human intervention (Onnasch and Roesler, 2021). This demands diverse innovation expertise, described in terms of advancements in AI and self-monitoring technology of the service robots, as well as the collaboration potentially involving interdisciplinary stakeholder teams comprising roboticists, AI researchers, domain experts, ethicists, policymakers, and end-users.
- The involvement of service robots varies in *integration* into the micro, meso, and macro levels of the ecosystem (Appio *et al.* 2021). Innovation management focus differs in terms of scope, encompassing user-centered design, coordination of organizational and community aspects, and the development of societal and policy frameworks. This approach also involves the inclusion of a potentially diverse array of stakeholders.

Table 6.2. Autonomy and ecosystem integration of service robot

	Low autonomy of the service robot	***High autonomy of the service robot***
High integration of service robot with the ecosystem	**Patient Assistant Robots*** Assist patients with tasks like delivering medication, guiding them to appointments, and providing companionship, making healthcare more accessible. *Autonomy* Limited to predefined pre-programmed tasks, no independent decision-making. *Ecosystem integration*: Work alongside medical staff, follow patient schedules, and are part of patient care plans. Integration involves training healthcare workers and ensuring data security and patient privacy. *Main goals for Innovation - Deployment* *Micro*: enhance patient care by providing 24/7 assistance, reducing the workload on healthcare staff, and personalizing patient care through data-driven insights. *Meso:* transform the healthcare industry by integrating advanced technology into patient care, leading to cost reductions and improved service availability. Emphasize workforce re-skilling to manage and integrate these robots effectively. *Macro:* address healthcare accessibility and continuity, especially in labor-constrained environments, and contribute to the overall efficiency of the healthcare system.	**Autonomous "Last Mile" Delivery Robots** Navigate city streets to deliver packages and goods to homes and businesses. They are equipped with advanced sensors and AI algorithms to safely interact with pedestrians, traffic, and smart infrastructure. *Autonomy* Integrated into the city's logistics network, they coordinate autonomously with warehouses, retailers, and consumers. *Ecosystem integration*: Government regulations, urban planning, and collaboration of private companies with city's authorities are essential for their sustainable deployment. *Main goals for Innovation - Deployment* *Micro*: offer efficient, convenient, and rapid delivery services directly to customers, enhancing customer satisfaction and meeting the demand for quick commerce. *Meso:* revolutionize the logistics and retail industries by introducing autonomous delivery solutions, thereby influencing market dynamics and competitiveness. *Macro:* foster sustainable urban development by reducing the carbon footprint associated with traditional delivery methods and shaping future urban infrastructure to accommodate autonomous delivery systems.

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Table 6.2. Continued

	Low autonomy of the service robot	*High autonomy of the service robot*
Low integration of service robot with the ecosystem	**Companion Robots** Offer vital emotional support and companionship. *Autonomy* Relatively low level of autonomy, all behaviors and interactions are pre-programmed. *Ecosystem integration*: They function relatively independently within the ecosystem and help users feel more engaged and less isolated. *Main goals for Innovation - Deployment* *Micro*: address emotional well-being by preventing loneliness and providing companionship, especially for individuals who may be isolated. *Meso:* create a new niche in the service industry focused on emotional and psychological support, potentially reducing the burden on mental health services. *Macro:* contribute to societal well-being by addressing mental health issues and social isolation, which are increasingly prevalent in many societies.	**Stand Alone Kiosk-Reception Robots** Serve as a welcoming presence, providing information, offering direction and enhancing overall experiences in various settings, including airports, hotels, and banks. *Autonomy* Operating with a relatively high degree of autonomy through pre-programmed features, these robots efficiently greet and assist visitors independently. *Ecosystem integration*: Standalone entities, simplifying deployment and minimizing the need for extensive integration efforts. *Main goals for Innovation - Deployment* *Micro*: Improve customer service by providing consistent and efficient information and assistance, thereby enhancing the visitor experience and supporting front-line staff. *Meso:* Offer a cost-effective solution for customer service across various industries like hospitality, banking, and transportation, influencing the way these industries operate and compete. *Macro:* Help mitigate labor shortages in service industries and ensure the availability of basic customer services, contributing to the smooth functioning of economic activities.

** The current study presents robot Ivy in its illustrative case. Ivy is a patient assistant robot that is characterized by limited autonomy and high ecosystem integration.*

Actor Roles in Ecosystems

In the initial phases of an innovation ecosystem's development, diverse stakeholders assume distinct roles (Dedehayir *et al.*, 2018). Adopting a role theory perspective (Biddle, 1986), Dedehayir *et al.* (2018, p. 18) characterize 'role' as a distinct set of behaviors or activities undertaken by stakeholders within the ecosystem. The emergence of an innovation ecosystem unfolds through three distinct stages (Dedehayir *et al.*, 2022).

The first stage, preparation, involves defining the value proposition and identifying stakeholders capable of realizing it. In this phase, the stakeholder assuming a leadership role takes charge, identifying and attracting various other stakeholders. Transitioning to the formation stage, the focus shifts from individual contributions to collective innovation efforts. Trust is cultivated, and connections are established. The stakeholder in the leadership role coordinates actions, while those in value creation roles contribute ideas on how the innovation ecosystem can operate. Stakeholders in value support roles share expertise and foster connections, and those in entrepreneurial roles set up the network (Clarysse *et al.* 2014). The final stage, operation, directs attention towards offering complementary services and facilitating inter-role transactions that yield additional value and ensure effective value appropriation within the innovation ecosystem (Adner, 2017). Here, the stakeholder in the leadership role orchestrates resource flows and promotes complementarity, while direct value creators focus on their specific contributions. Value support roles involve establishing technology and/or market access, while entrepreneurial stakeholders within the ecosystem forge connections with other stakeholders.

The following chapter presents an illustrative case of an ecosystem comprising public (regulated and state-funded) and private (for-profit and self-financed) stakeholders effectively addressing the quality of care in light of increasing labor shortages by strategically integrating service robots into long-term care. To understand the complexities of innovation management for Public Value, we selected a case highly integrated into the micro (user), meso (organizational), and macro (societal) levels of the ecosystem. At the same time, selecting a case with lower autonomy enables us to zoom into the impact of large-scale service robot deployment in the field, given that most autonomous service robots currently are limited in scope (e.g., Amazon tested its delivery robots for a limited time and with few recipients) or location (e.g., Stand Alone Kiosk-Reception Robots are confined to the reception area and tasks). Hence, our following case exemplifies how ecosystems surrounding Service Robot-based Innovation apply the concept of Public Value Innovation in a real-world setting.

6.3 ILLUSTRATIVE CASE: IMPLEMENTING SERVICE ROBOT-BASED INNOVATION IN A REGIONAL HEALTHCARE ECOSYSTEM

6.3.1. Case overview

The innovation ecosystem we are examining is based in the Netherlands. Our investigation targets individuals with mental health issues, such as epilepsy and anxiety, who reside in one of six long-term care facilities. Our fieldwork, focusing on integrating the service robot Ivy into this ecosystem, began in March 2023 and is expected to conclude in September 2024. The manuscript emphasizes insights from field notes recorded during network meetings, providing a detailed view of the ongoing research and understanding of the 'ecosystem-as-structure' and innovation management in this case. The present ecosystem has been devised with the aim of alleviating the labor shortage within the long-term care sector. This endeavor revolves around the implementation and scale-up of service robots, while maintaining a strong commitment to delivering long-term care that is user-centric, affordable, accessible, and of the highest quality. The stakeholders in the ecosystem comprise six independent long-term care providers (public), each catering to a diverse spectrum of vulnerable patients (private). Instead of referring to 'patients', our illustrative case adopts the term 'clients' commonly used in practice and theory of long-term care, distinct from acute care and treatments in hospitals or emergency centers. Additionally, it includes governmental co-funding (public), one health insurance provider (public), one technology provider (private), and two research institutes (public).

This illustrative case encompasses all four defining components of the ecosystem-as-structure framework. To begin with, the alignment among stakeholders in the regional ecosystem became apparent in preparatory meetings in which joint ambitions were defined. Positions, roles, and flows within the ecosystem were formally agreed upon. For example, all the long-term care providers committed to implementing at least one robot, the research institutes committed to monitoring the different steps in the implementation process, while the technology provider identified the ICT requirements available and needed at the premises.

Secondly, interactions among stakeholders in the innovation ecosystem take place across relationships. Every long-term care provider proposes a client that could benefit from the introduction of a robot. Caregivers from the long-term care provider, the technology provider, and the research institutes are present to assess the client's needs multilaterally. The third component covers the set of stakeholders jointly creating the value proposition. The long-term care provider involves caregivers who program the robot, while the research institutes add value by monitoring the implementation process. The technology provider, for instance, ensures that the robot has internet access on the premises of the long-term care provider. Finally, the materialization of the value proposition can be described as offering affordable and accessible high-quality care amidst labor shortages. For instance, a robot might help a client wake up and start the morning routine, saving the formal caregivers time and effort in this recurring task.

6.3.2. Employment of service robot "Ivy"

The ecosystem introduces service robot Ivy (a visual shown in **Table 6.1)** in six independent long-term care facilities for approximately fifty clients. Ivy has the potential to augment caregiver capabilities, optimize care routines, and provide user-centric support to clients, thereby elevating the overall care experience for clients and frontline care employees. We introduce *Service Robot Ivy* according to the characteristics operationalized in section 6.2.1 and its ecosystem integration as presented in section 6.2.4.

Robot aesthetics and assistive role. Ivy has a physical embodiment, which allows the robot to interact with its environment (Ziemke, 2003) easily. More specifically, in terms of *aesthetics,* human-like features such as a face, body, arms, legs, and the use of voice characterize the morphology of the robot. Ivy is capable of fulfilling different roles, but mainly provides cognitive support (e.g., agenda reminders) and fulfills social needs (e.g., initiates a conversation or game). The robot's *assistive role* is more social than functional or physical (Jörling *et al.*, 2019).

Autonomy. Service robots can possess different levels of autonomy, allowing them to make decisions and operate without constant human intervention (Lee *et al.*, 2016). Ivy is not capable of making its own decisions but can operate without continuous human intervention after being programmed by a human. However, the robot's *proactivity* is limited, as it is confined to executing the interactions programmed by the FLEs.

User interface. In the case of service robots in restaurants (Odekerken-Schröder *et al.*, 2022; Schepers *et al.*, 2022), the user interface for customers and FLEs is often identical. In these settings, both FLEs and customers interact with service robots using a touch screen for tasks like ordering, food delivery, and clearing tables, complemented by the robot's voice and screen-based visual communication. In the current illustrative case of service robot Ivy, it is very important to disentangle the worker-facing and client-facing interface of the technology (van Doorn *et al.*, 2023). The client might only see the robot, but in the case of service robot Ivy, FLEs design and program the interactions executed by Ivy in a browser-based online platform.

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Frontline employee-facing interface. FLEs, in our case the formal caregivers such as nurses and other healthcare professionals directly involved in the patient's care, design client interactions (e.g., agenda- medication- reminders, questions, stories) in a browser-based online platform. These programmed interactions are then either scheduled to be performed by the robot at certain time slots in case of plannable care, or can be proactively activated by clients by pressing a button that corresponds with a programmed interaction (e.g., a client asks the robot to tell a joke or a client who struggles to communicate with others, could use the robot to "communicate" on his/her behalf). Regarding the service robot's *manipulability*, FLEs can customize the client's experience by designing specific interactions.

Client-facing interface. Ivy communicates with the client with a human-like voice but does not respond to voice. These interactions are voice-based and can be accompanied by pictograms in case of a more visually oriented client. Interactions can range from one-way communication, like a morning reminder from the robot (e.g., "Good morning. It is time to get up, get dressed and start the day"), to two-way exchanges that ask for client responses (e.g., "How are you doing?"). In addition to voice, Ivy can simultaneously communicate using text and pictograms while clients can interact with Ivy through a touch screen.

Ecosystem integration. Ivy carries out essential care tasks for clients, but only if interactions are programmed and FLEs provide input. This integration not only exemplifies the advanced capabilities of modern service robots but also underscores the potential for a transformative impact on these micro-level stakeholders of the ecosystem. To ensure Ivy's operational effectiveness in direct care, both the organization's ICT department and the technology provider must maintain a secure, closed, and reliable internet connection. In addition, the technology provider offers direct support to FLEs encountering issues with the robot.

Main goal for innovation. Service robot Ivy has implementation goals defined on different levels. On a *micro level*, Ivy offers value for clients and FLEs. Specifically, Ivy enhances client care by providing 24/7 assistance and personalizing patient care through data-driven insights. Moreover, Ivy unburdens FLEs by augmenting and substituting human tasks. On a *meso level,* personal assistance robots, such as Ivy, transform the healthcare industry by integrating advanced technology into patient care, leading to cost reductions and improved service availability. Besides the FLEs' willingness to collaborate with service robots (Paluch *et al.*, 2022), organizations can re-skill the workforce, allowing them to manage and integrate these robots effectively. The deployment of personal assistant robots also addresses *macro level* objectives. Service robot innovation can improve the affordability, accessibility, and continuity of long-term care services, thereby mitigating human labor shortages in labor-constrained environments and contributing to the overall efficiency of the healthcare system.

6.3.3. Roles per stakeholder in the innovation ecosystem

After having introduced the service robot Ivy, we now illustrate the four strategic choices that have been made to involve different stakeholders (Juntunen *et al.* 2019). First, the stakeholder network covers a wide breadth ranging from healthcare insurance, long-term care provider, technology provider to research institutes, each having their focal roles. Secondly, a selection of primary and secondary stakeholders is included, referring to stakeholders without whom the value proposition could not be realized (e.g., the long-term care providers). The next strategic decision refers to ensuring the quality of organizational engagement. In the innovation ecosystem at hand, the organizational engagement of all stakeholders is high, given their top management involvement, their collaborative work, and their willingness to disclose organizational information. Finally, the timing of integrating stakeholders is straightforward, as all stakeholders have been involved simultaneously from the preparation stage onwards, collaboratively defining a value proposition that underlies the ecosystem.

Understanding the innovation ecosystem's composition requires exploring the roles of the involved stakeholders in realizing the common value proposition (Dedehayir *et al.*, 2018). These roles, spanning from pivotal leadership to catalytic entrepreneurship, bring to light the dynamics of stakeholders within the so-called genesis of the innovation ecosystem and their interconnected contributions. Notably, these roles do not always emerge exclusively, and it is evident that many stakeholders take on multiple roles. Understanding these stakeholders' core roles and activities is crucial to comprehend the genesis of an innovation ecosystem and its scale-up potential.

The National Healthcare Insurance. This stakeholder takes on the role of innovation ecosystem leader in the joint Public Value Innovation and focuses on forging public and private partnerships and governance of the ecosystem. In the preparation stage, the healthcare insurer took responsibility for attracting and gathering relevant stakeholders, forming links and alliances with organizations that owned various resources from different industries, stimulating complementary investments, and providing opportunities. In the ecosystem formation stage, the healthcare insurer coordinates interaction and fosters collaboration and collective action (Ritala 2023), by organizing joint meetings and encouraging exchange of learnings. In the operation stage, the healthcare insurer takes a leadership role in the innovation ecosystem by orchestrating (monetary) resource flows between the stakeholders and fostering complementarity.

Long-term care providers. During the preparation stage of the innovation ecosystem, a larger set of potential long-term care providers was identified, including the current six that ultimately decided to join the innovation ecosystem. Only in the formation stage, these public stakeholders showed their commitment and started taking a direct value creation role by using the service robot for specific use cases. Consequently, they also engaged in purchasing or licensing of the robots, aiming at simultaneous value creation for clients and FLEs. In the current operation stage of the innovation ecosystem, FLEs employed at a long-term care provider, define a problem or need on the client level, which then leads to the development of ideas on how to implement service robot Ivy in a need-centric way. The client's caregiver (e.g., FLE) also supports primary value creation by taking on an expert role, where a client's need or problem is also defined based on the caregiver's expertise. Besides the primary stakeholders involved, privacy officers of the legal department or the ICT department at the long-term care providers' institutions also support value creation by offering their expertise. As soon as implemented, the client interacts with the robot and performs a user role by simply using and giving feedback.

Research institutes. The public research institutes within this innovation ecosystem primarily assume an expert role and give credibility to the ecosystem, similar to other localized ecosystems involving universities or public research organizations (Clarysse *et al.*, 2014). In the preparation stage, the research institutes were identified to provide their expertise in monitoring the implementation. In the operation stage, these stakeholders aim to support the other stakeholders by monitoring the implementation of the social robot in the innovation ecosystem and generating insights about the innovation implementation from basic and applied research.

Technology provider. Although not the ecosystem leader, the private technology provider performs a key role by being very entrepreneurial and by taking a holistic approach to the onboarding of the long-term care providers. In the preparation stage, the technology provider provided robots, programming resources and onboarding meetings with different stakeholders within all 6 long-term care providers. This entrepreneur also identified potential other relevant stakeholders to expand the innovation ecosystem in the future. In the formation stage, the entrepreneur designed and provided the technical basis (e.g., service robot hardware and software, a browser-based online platform to program the robot), bundled an offering of different components, allowing other stakeholders to create value for the end-users. The technology provider takes care of the network and the ICT infrastructure and trains the caregivers in using robot Ivy, which enables the innovation implementation. Ritala (2023) refers to this organizational element as 'generativity'. In the operation stage, the entrepreneur reaches out to potential new stakeholders who can benefit from joining the innovation network.

Table 6.3 summarizes the role distribution per stakeholder within the innovation ecosystem across the different stages of ecosystem development.

Table 6.3. Roles per actor in innovation ecosystem

		Stage in Innovation Ecosystem Genesis		
Stakeholder roles in the innovation ecosystem (Bedehayir *et al.* 2018)	Stakeholders in the illustrative case	*Preparation*	*Formation*	*Operation*
Leadership	National healthcare insurance	Attracts and links partners	Coordinates interactions and creates collaboration	Orchestrates resource flow and fosters complementarity
Direct value creator	Long-term care provider		Shows commitment	Identifies use cases and offers resources
Expert	Research institutes		Provides expertise	Monitors progress and provides expertise
Entrepreneur	ICT provider	Provide resources, co-locates potential partners	Sets up the network and co-develops the offering	Links to other actors

6.3.4. Three levels of the innovation ecosystem

After examining the different stakeholders, we describe the levels of the innovation ecosystem where these partners interact in practice. To organize the decision-making processes for implementing service robots in long-term care, we use a framework that categorizes the discourse into macro, meso and micro levels of analysis (Appio *et al.*, 2021). This approach enables us to confront our findings with current theorizing in innovation management.

The *macro level* explores the evolving dynamics in the relationships among long-term care providers within innovation ecosystems (Carayannis and Campbell, 2009). We consider all involved long-term care providers, the national healthcare insurance, the technology provider and the research institutes to coordinate interactions, collaborate, and develop the value proposition at the macro level of the ecosystem. All stakeholders in the ecosystem must work together to tackle issues like adoption, needed capabilities, technical problems with the service robots, and outdated elements resulting from changing user needs. This collaboration helps maintain system integrity and improve the accessibility and functionality of service robots and their resulting innovations in caring for and with clients (cfr. Hilbolling *et al.*, 2021). Although the stakeholders at the macro level committed to ecosystem participation in a relatively short time span of roughly three months, the actual implementation of service robots in each of the individual long-term care organizations at the meso level took up to twelve months. On the strategic macro level, representatives (e.g., members of the management team, innovation managers) met monthly in a network group to share experiences and learn from each other. The significance of feedback loops becomes evident as frontline caregivers provide critical input on aspects where robot Ivy falls short, necessitating adjustments to the overall strategy. This emphasizes the crucial role of cohesive decision-making spanning macro, meso, and micro levels in the innovation ecosystem, highlighting the importance of translating strategic intentions into concrete actions.

The intermediate *meso level centers on* how innovations have direct implications for the capabilities, processes, routines, and business models of public long-term care organizations. We consider all involved stakeholders within the long-term care providers as partners at the meso level, ranging from innovation management departments and management boards, to privacy officers of the legal department, to ICT departments that are involved in ensuring the proper functioning of the service robot hardware and software on location. It becomes evident that the cognitive and emotional expenses associated with the deployment of service robots, as outlined by Lanzolla *et al.* (2021), necessitate careful consideration by innovation managers within long-term care organizations. At the cognitive level, for example, we noticed several formal caregivers had difficulty imagining what the service robot could do to their clients. Emotionally, few formal caregivers express a concern about losing their jobs.

Finally, we examine the *micro* level, in other words, the individuals (e.g., clients and caregivers) and teams (of caregivers) within these long-term care organizations. These constellations typically consist of the client, the involved family member (e.g., informal caregiver(s)), the service robot and a team of formal caregivers and hence are more encompassing than established service triads (Odekerken-Schröder *et al.* 2022). The functionality of the service robot and the roles performed depend on the client's needs, while the caregivers are empowered and in charge of instructing and employing the robot. For instance, in one constellation, the service robot contributes to the client's independence by giving reminders, in another constellation, the robot focuses more on activating a client, and in a third constellation the robot serves a

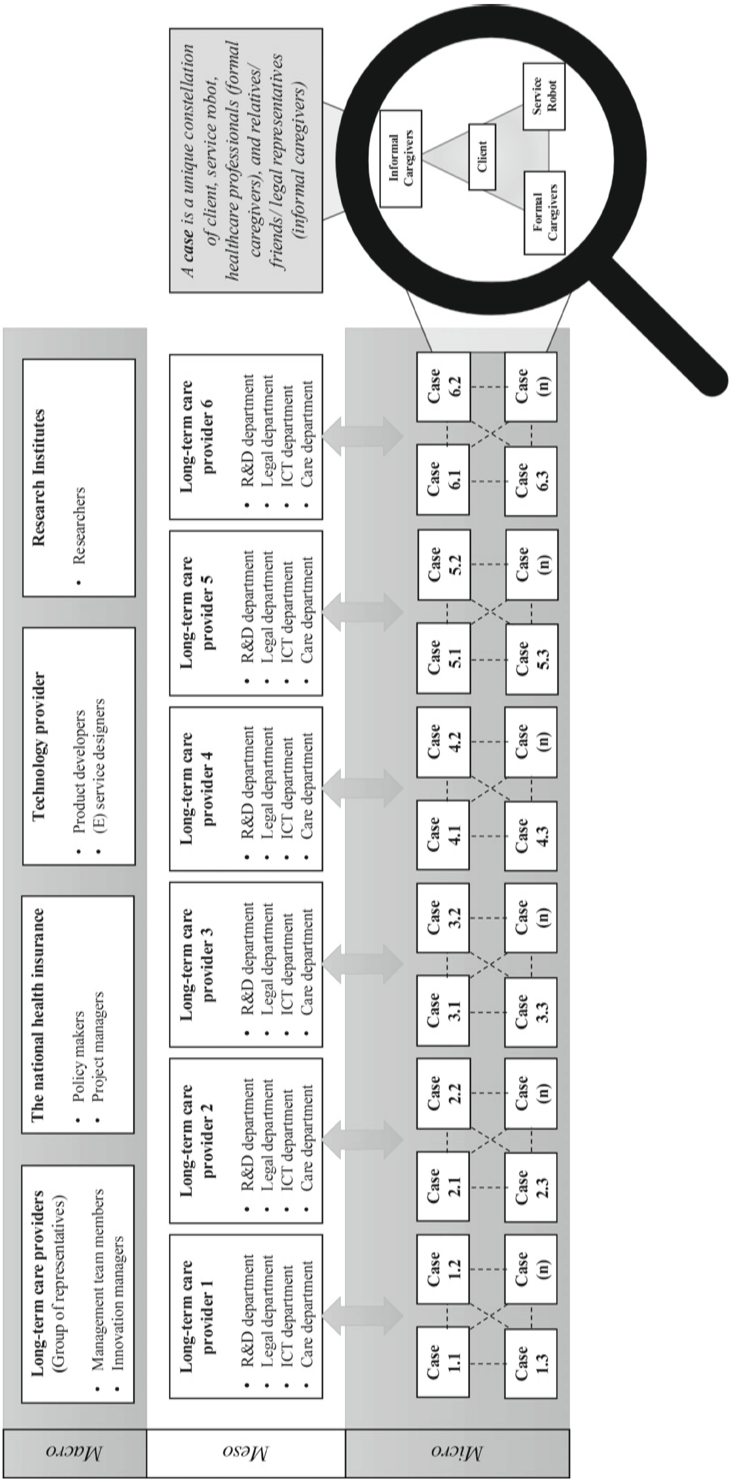

Figure 6.1. The innovation ecosystem, visualized by cases (micro level), nested within six long-term care providers (meso level), that collaborate with other organizations (macro level)

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more social purpose by being more conversational, asking how a client is doing or cracking jokes, contributing to a happier and more meaningful life.

Figure 6.1 visualizes the ecosystem and its stakeholders on corresponding levels. This case illustration allows us to explore the implementation of service robots that tackle contemporary societal challenges involving aging populations, labor shortages, and technological disruption.

6.4. DISCUSSION

This article asserts that creating Public Value through implementing and scaling up service robots is inherently tied to innovation management utilizing the ecosystem-as-structure perspective, consisting of different stakeholders at the micro, meso, and macro levels. By conceptualizing Service Robot-based Innovation and analyzing a practical implementation in long-term care, this study holds several implications for theory and practice.

6.4.1. Theoretical implications

Firstly, our research synthesizes prior studies from marketing, design, human-computer interaction, and robotics to conceptualize service robots within the innovation literature. Operating in relatively unstructured environments, the human-machine symbiosis demands a degree of autonomy. This allows service robots to assume roles that are both substitutive and augmentative to human employees (Odekerken-Schröder *et al.*, 2022). Additionally, their integration into ecosystems and direct interactions with FLEs and customers (Wirtz *et al.*, 2018) significantly impacts the approach to innovation management and distinguishes service robots from robots in industrial environments. By exploring the heterogeneity of service robots, we demonstrate how variations in characteristics (e.g., autonomy, aesthetics, assistive role, and user interface), ecosystem integration, and the user interface of service robots have implications for innovation management practices and drive value creation at the three different levels of innovation ecosystems. Our comprehensive conceptualization delineates Service Robot-based Innovation as both the development and deployment of robots within an ecosystem to add value across individual, organizational, and societal levels, thereby shifting focus from mere design to the services provided and the role of the broader ecosystem. This perspective not only moves beyond viewing service robots as isolated smart products but also underscores the necessity of their integration into service contexts (Raff *et al.*, 2020).

In addition, this article establishes a conceptual connection between the emerging phenomenon of Service Robot-based Innovation and current literature streams in innovation. Specifically, the service robot's autonomy and underlying AI, or its ability to make decisions without human intervention, requires specific innovation capabilities for AI adoption (Gama and Magistressti, forthcoming). Our case on Public Value points towards research opportunities, particularly concerning the interaction of such ecosystem capabilities and AI governance, involving, for example, an ethical code and a council with representatives from all stakeholders. Moreover, it explores the aesthetics of service robots, which may manifest in the physical appearance resembling animals or machines. This introduces variation to the well-established literature on product design, where features, aesthetics, and ergonomics are crucial factors influencing customer responses (Moon, Park, and Kim, 2015). In contrast, the service robot's assistive role bridges our study with the service innovation literature. A combination of functional and social robot functionalities delivers value within specific service environments when integrated effectively with the current FLE team and the overall operations, potentially leading to the augmentation or substitution of current staff (De Keyser and Kunz, 2022). The fourth characteristic is the user interface that facilitates human-robot interaction (HRI), enabling users to customize and tailor their experience. The development of anticipatory assistance and proactive engagement of such service robots expands existing literature on user involvement and innovation adoption, connecting with longstanding work in Human-Robot Interaction (Song and Kim, 2022).

Next, the examination of innovation ecosystems for Service Robot-based Innovation reveals the dynamic involvement of diverse stakeholders across different developmental stages as a key theoretical implication. Acknowledging the ecosystem-as-structure perspective (Jacobides *et al.*, 2018), our study underscores that the orchestration of strategic decisions involves stakeholders assuming specific roles in various levels—micro, meso, and macro (Appio *et al.* 2021). Service robots impact client experiences at the micro level, demanding adaptability from formal caregivers. The meso level emphasizes the crucial role of long-term care organizations in deploying service robots as assets to address staffing challenges, necessitating readiness in infrastructure and compliance. Meanwhile, at the macro level, the transformative role of service robots in human-centered ecosystems emphasizes collaborative efforts for Public Value Innovation. This theoretical insight highlights that effective innovation ecosystems necessitate dynamic and adaptive roles at each stage, involving stakeholders in leadership, value creation, support, and entrepreneurial roles (Bedehayir *et al.*, 2018). Understanding and managing these roles strategically is imperative for ensuring coherent collaboration. Beyond the roles, the ecosystem-as-structure approach enables us to delineate the alignment structure of the multilateral stakeholders and illuminate the (overall and individual) value proposition and activities of these stakeholders. Complexity stems from the long-term perspective, from the gradual transformation of strategic intentions into tangible actions, and the dynamics of stakeholders within the ecosystem, representing key challenges in aligning the shared value proposition across the various ecosystem levels.

This research also highlights the pivotal role of innovation management in creating Public Value through leveraging the resources of public and private stakeholders (Ritala, 2023; Spanjol *et al.*, 2024), where solely market-driven solutions are not readily available. In our context, innovation for Public Value encompasses the conception, development, and realization of products and services that utilize service robots. It inherently involves interactions between the private and public sectors, focusing on generating societal value, contributing to the emerging literature on Public Value theory (Mazzucato and Ryan-Collins, 2022). Our illustrative case demonstrates how a PVI ecosystem, different from a market-based one, establishes dependencies, common goals, and complementary knowledge and capabilities, which are crucial in creating Public Value. A national healthcare insurer serves as an orchestrator guiding choices within the ecosystem network—such as breadth, types of stakeholders, timing of involvement, and forms of collaboration. Our findings contribute to the implementation of PVI by exploring how the public's need for affordable, accessible, and high-quality care translates into individual needs. Alignment among the stakeholders is founded on the ecosystem's dedication to openness and learning, fostering information sharing and mutual understanding among PVI partners (Alam *et al.*, 2022). Simultaneously, the clear, complementary roles taken by various stakeholders acknowledge their different goals and business models.

6.4.2. Managerial and policy implications

In addition to the research directions, our article presents several practical takeaways for stakeholders considering or leading Service Robot-based Innovations. To begin with, our study emphasizes the significance of developing a detailed stakeholder engagement strategy for the macro-level that encompasses all parties from the preparation phase to the implementation of the innovation. This involves identifying who should be engaged, when they should be engaged, for what activities, and through which cooperative mechanisms. Across industries, several situations have been reported where robot-based innovations sometimes fail, such as the therapeutic seal robot Paro, which is meant to help soothe and engage patients, or interactive service robots in retailing, which are intended to assist customers with locating products and providing information. Despite possessing adequate technical capabilities, these robots often fail to integrate into the business environment, beyond a novelty effect that wears off quickly without substantial, sustained engagement from customers (Carlin, 2019). Our case demonstrates the importance of involving a diverse range of stakeholders, from healthcare service providers to users, technology suppliers and research institutions. Particularly noteworthy is the experience of the IT provider in overcoming resistance to change, instilling confidence in healthcare organizations regarding the implementation process. Managers and involved policymakers in other settings should similarly identify and engage all relevant stakeholders early in the implementation process to align goals, share expertise, foster collaboration, and strive for a common value proposition.

Another managerial implication for decision makers on the micro-level pertains to the characteristics of the identified robots, offering guidance within the rapid expansion of robot types in the market. Distinct characteristics such as autonomy, aesthetics, assistive roles, and user interfaces are crucial for deciding about the set-up of the innovation process stages, the needed expertise, and fostering cross-departmental collaboration. Furthermore, determining the integration of service robots into the ecosystem encourages managers to not only integrate external stakeholders in their innovation process but also to assess the value creation at various internal service levels and ensure coherence between them.

Finally, our findings point toward balancing coordination, collectivity, and generativity as a meso and macro-level collaboration mechanism. It is crucial for the stakeholders, across and within the ecosystem levels, to adaptively respond to technological advancements and changing user needs. Given the long-term nature inherent in Public Value Innovation, as described in our illustrative case, policy advisors should foster public-private collaborations to learn from each other, adapt based on key insights, and scale robot-based innovations. Crucial input is provided by micro-level activities where a triad of service robot, human staff member (e.g., formal caregiver), and customer (e.g., healthcare clients), along with other customers (e.g., informal caregivers like family members), need to be involved in Service Robot-based Innovation. In our illustrative case, formal caregivers were trained and assigned to identify clients who would benefit from the service robot. These trainings and their involvement not only mitigated the risks of underutilization of service robots but also provided continuous feedback spread across all levels, ensuring long-term use and successful service delivery.

6.5. FUTURE RESEARCH AGENDA

Building upon the discussion on service robots, Public Value, and innovation ecosystems, this article establishes a robust foundation for Service Robot-based Innovation within an ecosystem and its respective levels to create Public Value. The focus on one single case is among the article's limitations that provide opportunities for future research. Rooted in an exploration of a long-term care setting, our research agenda also derives inspiration from the scaled-up deployment of service robots in a user-centered approach. For example, our findings highlight the critical role of stakeholders in successful collaboration and how a service robot's autonomy affects the demands placed on these stakeholders. This inspires further investigation into how varying degrees of robot autonomy influence the distribution of responsibilities among actors at the micro level.

Table 6.4 delineates our future research agenda, which explores critical research themes within and across the three levels of an innovation ecosystem. Specific research directions that aim to address existing gaps in innovation management literature and practice accompany each theme. Next to guiding future scholarly inquiries this research agenda also aims to inform policy-makers and practitioners about the strategic deployment of service robots to create Public Value.

Table 6.4. Future research agenda: Exploring Service Robot-based Innovation in creating Public Value

Ecosystem level	***Research theme***	***Research direction***
Macro	Ethical and societal issues	• Exploring the ethical and societal implications of integrating service robots across various industries, including long-term care. • Developing societal and regulatory frameworks for ethical Service Robot-based Innovation and compliance. • Investigating the effects of labor and economic effects of deploying highly autonomous service robots in public spaces and communities.
	Scaling innovation adoption	• Defining barriers and access challenges in innovation management approaches for scaling up the integration of service robots. • Developing strategies to enhance the accessibility and usability of service robots' interfaces across different user groups, with a special focus on vulnerable users such as the elderly and those with disabilities.
	Long-term innovation impact assessment	• Understanding the impact of service robots and the evolution of roles within innovation ecosystems and defining the effects on labor markets, industries, and societal attitudes, by conducting longitudinal studies.
	Innovation regulation and policy	• Developing regulatory frameworks and policies pertinent to innovation management in the deployment of service robots with different levels of autonomy. • Assessing the roles of regulatory bodies and industry standards. • Exploring the roles of policymakers in creating supportive ecosystems for the innovative use of service robots, ensuring public safety and privacy.
	Public-private partnerships in innovation	• Understanding the role of public-private partnerships in ecosystem-level innovation strategies to address societal challenges, while also ensuring sustainable innovation practices. • Investigating how public entities can actively drive and shape innovation through public-private partnerships, focusing on their role in initiating, coordinating, and accelerating Service Robot-based Innovations.

Table 6.4. Continued

Ecosystem level	***Research theme***	***Research direction***
Meso	Innovative quality metrics	• Developing novel indicators, scales and frameworks to assess the innovation performance facilitated by service robots across various domains, underscoring their impact on outcomes, stakeholder satisfaction, and overall performance.
	Data privacy and security in innovation	• Addressing data privacy and security concerns in the context of service robots collecting sensitive information of users and developing robust innovation management frameworks for data protection.
	Collaborative design	• Designing services in which service robots are integral components, going beyond their physical design to encompass the full-service experience. • Identifying effective collaboration models and practices that bring together various actors such as technology providers, service designers, frontline employees (FLEs), and end-users to create holistic service solutions.
	Innovation governance	• Identifying different collaborative governance models to orchestrate innovation efforts and ensure the successful integration of service robots at the meso level. • Investigating how organizations can strategically manage their ecosystems to accommodate service robots, including the selection of key roles and stakeholders at various stages of ecosystem development.
	Training and skill development	• Understanding how human-robot collaboration can be fostered and designing innovative programs to foster seamless human-robot collaboration. • Exploring how varying levels of autonomy in service robots necessitate changes in workforce training and management practices within organizations.
	Cost-benefit analysis	• Conducting in-depth cost-benefit assessments to gauge the financial implications of incorporating service robots into different business models. Identifying innovation management strategies to optimize financial outcomes. • Analyzing the impacts of assistive roles (social vs. functional) of service robots on the efficiency and value creation in environments where robots work independently or as part of human-robot teams.

Table 6.4. Continued

Ecosystem level	***Research theme***	***Research direction***
Micro	Human-Robot Interaction & Innovation Adoption	• Explaining how various user groups adopt different types of service robots, in long-term care and other sectors, resulting in innovation management and adoption strategies to enhance robot acceptance and user-centricity.
	Customized Innovation Solutions	• Understanding micro level innovation dynamics to optimize the design and functionality of service robots to meet individual user needs effectively.
	Interplay of Service Robots and Actor Roles	• Exploring the intersection between autonomy levels in technological innovations and the roles assumed by actors within innovation ecosystems. • Investigating how varying degrees of robot autonomy influence the distribution of responsibilities among actors.
Holistic ecosystem	Learning from use activities	• Identifying different types of learning, capturing the interplay between user-driven and provider-driven innovation, shedding light on how knowledge transforms into impactful technological breakthroughs and potential further scale up. • Explaining how users and designers (e.g. technology providers) both play a role in the use of new technology and also in the design and further development in an ecosystem • Identifying best practices for managing the transition of service robot innovations from lab to market, considering the interplay of autonomy, aesthetics, assistive roles, and user interface, to ensure long-term usage and societal benefits. • Investigating the factors influencing role transitions and the impact of role dynamics on the effectiveness of innovation ecosystems, through longitudinal studies tracking the evolution of roles, the adaptive capacities of actors and the implications for Public Value creation.
	Dynamic Role Adaptation in Innovation Ecosystems	• Zooming into the cases varying in levels of autonomy and ecosystem integration to delineate distinct innovation processes and management structures.
	Innovation management varying in ecosystem integration and autonomy	• Developing frameworks for cross-level ecosystem strategies that facilitate the collaboration between micro, meso, and macro levels, ensuring that service robots contribute effectively to Public Value creation.

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By pursuing these research directions, both scholars and practitioners can contribute to a profound comprehension of how service robots propel innovation within ecosystems across industries. This pursuit is driven by the intent to jointly contribute to Public Value.

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CHAPTER 7

DISCUSSION

7.1. SHIFTING GEARS - A RECAP OF THE RIDE

This dissertation investigates how different types of physically embodied service robots, varying in their levels of autonomy and customization by end-users, interact with various constellations of human actors and create value across diverse service settings. Drawing upon Actor-Network Theory (Law & Hassard, 1999; Sayes, 2014), which suggests that constellations of humans and non-human entities interact as part of a network co-creating meaning and shaping the actions of each other, this research examines service robots in increasingly complex constellations of actors. While existing research has primarily focused on dyadic interactions between one type of user (e.g., one customer or one employee), this dissertation aims to capture the social complexity surrounding HRI in authentic service environments. Consequently, all chapters in this dissertation deliberately adopted a field-first approach, focusing on the empirical investigation of real-world implementation as a foundation for engaging with theoretical perspectives. This strategy aligns with the calls for more field studies in service robot research that were prominent when this dissertation journey began in 2021 and remain relevant today, as field research in this area continues to be scarce (De Keyser & Kunz, 2022; Odekerken-Schröder *et al.*, 2022; van Doorn *et al.*, 2025). Controlled experiments often fail to capture the social complexity surrounding HRI (Lu *et al.*, 2020). For instance, in hotel or restaurant settings, customers often experience service robots as part of a group, collectively dealing with and making sense of their robot encounters - a dynamic that influences their shared understanding of the technology and subsequent behaviors (Chapter 3). This social context is not only inherently tied to real-world contexts but also derives their meaning from them, making them difficult, if not impossible, to fully replicate in controlled laboratory environments.

The field data for this dissertation was collected in The Netherlands, a decision driven by both practical and strategic considerations. Access to industry partners was facilitated through my position as a co-founding member of The Maastricht Center for Robots (Maastricht University - MCR, n.d.), while the global COVID-19 pandemic necessitated flexibility in data collection planning, particularly regarding the intended research activities at Queensland University of Technology in Brisbane, Australia. Beyond these pragmatic factors, The Netherlands provides an ideal context for this investigation, combining a service-oriented economy with high technology readiness and adoption rates (Portulans Institute, 2024). By examining real-world implementations across hospitality, education, and healthcare settings, this research provides insights into how various constellations of actors interact with, adapt to, and customize service robots in their daily environments. A summary of the findings is presented below.

7.2. THE ROAD OF DISCOVERY - SUMMARY OF FINDINGS

The investigation begins with a service triad in hospitality (Chapter 2), progressing through collective customer experiences in hospitality (Chapter 3), team interactions in hybrid education (Chapter 4), and implementation cases in healthcare (Chapter 5), before advancing to a broader ecosystem perspective on Service Robot-based Innovation (Chapter 6).

Actor-Network Theory (ANT; Law & Hassard, 1999) provides a valuable theoretical lens for illustrating the synergetic connections between the chapters in this dissertation. More specifically, through this lens, the findings demonstrate that successful service robot implementation requires careful consideration of the constellation of non-human (e.g., service robot) and human actors, as well as their roles and relationships in such networks. Each chapter, standing as independent research projects, provides unique insights into these constellations, emphasizing how robots can transform relationships between human actors (Phillips *et al.*, 2023). Together, the chapters form a comprehensive understanding of how service robots drive transformation in service delivery across industries (De Keyser & Kunz, 2022; Lu *et al.*, 2020).

Our investigation began with Chapter 2's examination of *service triads* in *hospitality* settings. In this chapter, service robots Amy and Akatar performed *a servant role*, primarily focused on delivering food and drinks while facilitating basic interactions in constellations of customers and human staff of the restaurant. The findings reveal that the service robot's perceived value - both utilitarian and hedonic - significantly influences customer repatronage intentions. However, this influence depends critically on frontline employee interaction quality. When robots demonstrate lower utilitarian value, high-quality FLE interactions can compensate, effectively augmenting the service experience. Conversely, when robots exhibit high utilitarian value, the customer's need to interact with FLEs decreases, suggesting potential for highly functional robots to substitute certain FLE tasks and thus replace human-to-human by HRI (Odekerken-Schröder *et al.*, 2022). *In line with the ANT perspective*, service robots in a servant role can fundamentally transform the relationship between customers and FLEs in the service triad - either by augmenting FLE capabilities, or potentially substituting FLE tasks (Odekerken-Schröder *et al.*, 2022). This transformation exemplifies what Phillips *et al.* (2023) refer to as the intrusion challenge - where service robots fundamentally alter existing relationships between human actors in service settings.

Chapter 3 broadened the scope to examine collective customer experiences with service robots in hospitality settings. In this chapter, service robots Relay and LuckiBot emerged as focal points that fostered interaction and collective sensemaking among customer groups. The findings demonstrate that customers' initial appraisals of robots as either challenges or threats drive distinct coping responses. Challenge appraisals lead to more diverse coping strategies - including problem-focused, emotion-focused, and support-seeking approaches - while threat appraisals primarily result in emotion-focused coping. Through coping with service robots during these collective service experiences, customers develop shared realities about the robot that influence important outcomes, including reduced switching intentions and enhanced relational service well-being (Steins *et al.*, 2024). Through the lens of ANT, these findings demonstrate how service robots, as focal points in the servicescape, transform how customers within group constellations interact not only with the robot but also with each other, together coping with it during collective service experiences.

Moving to a specific constellation of actors in an educational setting, Chapter 4 investigated how telepresence robots influence group dynamics in hybrid teams of on-site and remote students in higher education. Robot TEMI's role is best described as a facilitator - enabling physical embodiment and mobility for remote students to establish presence and engage naturally with on-site peers in collaborative learning activities. The quantitative findings reveal that students in experimental groups with telepresence robots reported higher levels of essential group conditions - social cohesion, psychological safety, and group potency - particularly during the early stages of the course, leading to enhanced student engagement. The qualitative findings provide context for these results, revealing that telepresence robots enhanced remote students' presence through physical embodiment and fostered empowerment via autonomous mobility, advantages not afforded by traditional virtual inclusion through a smart screen. This reduced presence asymmetry facilitated more natural interactions between remote and on-site students. Notably, on-site students perceived their remote peers using the telepresence robot as more engaged and valuable contributors to the classroom, leading to more inclusive behaviors driven by both self-interest (benefiting from contributions) and reciprocity (matching increased effort). Looking at these findings through the ANT lens, Chapter 4 demonstrates how service robots, as a frontline service technology, facilitate interactions and transform traditionally asymmetric relationships between remote and on-site students into more equitable, engaging, and inclusive interactions, thereby enhancing learning in hybrid team settings. The TPR augments remote students' capabilities and enables them to establish a stronger physical presence to more naturally engage in collaborative learning activities (De Keyser *et al.*, 2019; Raes *et al.*, 2020).

Chapter 5 examined how service robots support both *healthcare professionals and people with intellectual disabilities (PwID)* in *long-term care settings*. Here, robot Ivy served as an *assistant*, providing cognitive support and fulfilling social needs for

PwID while serving as a support for healthcare professionals to enhance care delivery. The findings reveal that sustained robot use depended on characteristics of both key stakeholder groups. For PwID, cognitive capabilities and care predictability were crucial, while for healthcare professionals, available time for programming and digital competency determined success. Through systematic analysis of both successful and discontinued cases, findings provide classifications of barriers as deal-breakers, obstacles, or minor hurdles, while categorizing facilitators as key drivers, enablers, or minor boosters. These factors span across client characteristics (e.g., cognitive capabilities), healthcare professional capabilities (e.g., digital competency), contextual factors (e.g., care predictability), and organizational support (e.g., available time for programming). After two months, robot use was sustained in 63% of cases (12/19), with key value emerging for both stakeholders. For PwID, this included enhanced daily structure through consistent reminders, improved emotional well-being through non-judgmental interactions, and increased independence. For healthcare professionals, benefits included reduced workload through automation, improved quality of client interactions, and reduced emotional burden. From an *ANT perspective*, these findings highlight how service robots can serve different groups of human actors simultaneously while adapting to their unique needs and capabilities. Moreover, the service robot performs different roles for these stakeholder groups, serving as a tool or extended self for healthcare professionals while acting as a companion and advisor for PwID.

Finally, Chapter 6 provided *a broader ecosystem* perspective on Service Robot-based Innovation. Robot Ivy is revisited in this chapter as *an enabler* of Public Value creation through ecosystem-wide innovation in *healthcare,* specifically *long-term care*. The findings highlight two key dimensions - the service robot's autonomy and its integration in the broader ecosystem - as critical determinants of collaborative innovation management practices and Public Value creation. Effective implementation requires alignment across micro (user), meso (organizational), and macro (societal) levels of the ecosystem, with different stakeholders assuming distinct roles throughout the ecosystem's development stages (Mahr *et al.*, 2024). Through an ANT lens, this multi-level perspective provides a comprehensive understanding of how Service Robot-based Innovation requires actors to perform certain roles and activities and transforms relationships between human actors across all ecosystem levels. For example, at the *micro-level constellation*, healthcare professionals often together with clients collaboratively customize the robot to meet specific care needs, transforming their relationship from one of care provision and receipt to one of co-creation. This collaborative approach then influences relationships at the *meso-level*, where different departments within healthcare organizations (e.g., ICT, legal, innovation) must align their activities to support this new form of care delivery, and at the *macro-level*, where public and private stakeholders forge new partnerships to enable this innovation.

The findings of this thesis not only advance theoretical understanding of HRI within different constellations of actors across a variety of service industries, but also provide practical guidance for organizations implementing service robots. The following section outlines the contributions of this dissertation and presents themes and questions for future research.

7.3. THE VIEW FROM THE SUMMIT - CONTRIBUTIONS AND FUTURE RESEARCH

While each chapter presents distinct contributions to theory and practice within its specific service context, several overarching themes emerge when examining this body of knowledge holistically. Guided by our overall research question, drawing upon Actor-Network Theory (Law & Hassard, 1999) as our theoretical foundation, these themes reflect how different types of service robots, performing distinct roles, influence and transform relationships between human actors across increasingly complex constellations. The progression from service triads in hospitality (Chapter 2) to ecosystem-wide implementations in healthcare (Chapter 6) reveals patterns in how service robots reshape service delivery across industries.

This section synthesizes the key contributions of the dissertation into three overarching themes. Specifically, it presents four theoretical contributions across two themes, while the final theme outlines three methodological contributions. First, by *moving beyond the dyad* (focus prevalent in existing literature), we examine how this dissertation advances understanding of service robot implementation through the study of triadic relationships and broader network perspectives. This approach highlights that successful implementation requires not only attention to immediate service interactions but also consideration of wider ecosystem implications. (Chapter 6 - Mahr *et al.*, 2024). Second, we discuss *how different robot types and roles*—particularly their potential for substitution or augmentation in the service frontline, as well as their levels of autonomy and customization—*influence relationships between human actors in different constellations* across service settings. Finally, we reflect on how *a field-first approach*—beginning with real-world robot implementations—guided the application of diverse theoretical frameworks across chapters, grounding them in empirical realities rather than preconceived theories. These themes not only synthesize the findings across chapters but also outline directions for future research and implementation efforts in service robotics. **Figure 7.1** illustrates these contribution themes alongside associated future research directions and key research questions.

7.3.1. Theme 1: Beyond the Dyad - The expanding peloton

Within the first overall theme, moving beyond the dyad, this dissertation makes two significant contributions by empirically examining actor constellations. First, it extends beyond the traditional dyadic focus prevalent in service robot research (Odekerken-Schröder *et al.*, 2022, Phillips *et al.*, 2023) by investigating HRI in increasingly complex constellations of actors across service settings. Second, it demonstrates how service robots transform relationships between human actors not only at the frontline but across micro, meso, and macro levels of service ecosystems (Mahr *et al.*, 2024). While existing research has primarily focused on micro-level frontline experiences of HRI (De Keyser & Kunz, 2022), this dissertation advances understanding by taking an ecosystem perspective that reveals how successful service robot implementation requires coordinated activities and resource deployment across macro and meso levels (Chapter 5 & 6).

HRI in complex constellations of actors

First, the dissertation's progression mirrors the expanding complexity of service robot implementation, aligning with its title, *Beyond the Dyad*, as it moves from triadic constellations to broader network perspectives. Beginning with the customer-robot-frontline employee triad in hospitality (Chapter 2), subsequent chapters examined increasingly complex constellations of actors: customer groups (Chapter 3), hybrid teams (Chapter 4), and the service triad of client-robot-professional caregiver in long-term care (Chapter 5). This expansion converged in Chapter 6's ecosystem perspective, demonstrating how successful service robot implementation requires alignment across constellations of actors on the micro (user), meso (organizational), and macro (societal) levels.

While early service robot research set important foundations by examining the dyad of one type of user (e.g., customer or employee) interacting with a service robot (e.g., Wirtz *et al.*, 2018; Wirtz & Zeithaml, 2018), HRI in real-world service contexts often involves multiple actors. Service encounters are often collective experiences (Carù & Cova, 2015), or characterized by the presence of third parties - actors beyond the focal actor that directly interacts with the service robot (Abboud *et al.*, 2021). The triadic analyses in this dissertation represent an important advancement in capturing the social complexity inherent to HRI, as service is increasingly provided by constellations of humans and robots (Larivière *et al.*, 2017; De Keyser *et al.*, 2019; De Keyser & Kunz, 2022). These more complex social environments and relationships between human actors fundamentally influence how interactions with robots unfold. Yet even these richer triadic perspectives cannot fully capture all interdependencies and collective value creation processes in service robot implementation, as demonstrated by the ecosystem-level insights in Chapter 6 (Mahr *et al.*, 2024).

A multi-level perspective on service robots

This theme's second contribution emerges through its ecosystem perspective on service robot implementation. While existing research has primarily examined frontline experiences of human-robot interaction (De Keyser & Kunz, 2022), this thesis reveals how successful implementation depends on organizational activities and resource deployment that span well beyond the service frontline. By examining implementation through an ecosystem lens, the findings demonstrate the critical importance of coordinated strategies across macro and meso levels (Spanjol *et al.*, 2024). Such a multi-level ecosystem approach might help prevent implementation failures (Blindheim *et al.*, 2022; Hung *et al.*, 2023), as it ensures consideration of all stakeholder needs and potential impacts across different levels of the service ecosystem (Mahr *et al.*, 2024 - Chapter 6). This multi-level perspective adds to recent work highlighting how organizational context shapes human-robot interaction (Castelo *et al.*, 2023), by demonstrating how sustained use of service robots transform relationships between human actors not just at the frontline, but across all ecosystem levels (Chapter 5 & Chapter 6).

The findings across chapters reveal an interesting pattern in how service robots create value within these complex constellations of actors. Like a peloton that expands and adapts to race conditions, service robot networks must remain dynamic and responsive to stakeholder needs. Notably, just as cyclists in a peloton compete while simultaneously cooperating, service robots operate in environments where they must offer comparative advantages over existing solutions. This dissertation indicates that successful implementation does not require robots to achieve perfection but rather to excel in specific aspects that enhance service delivery relative to current alternatives. For example, in Chapter 4, the telepresence robot did not need to replicate all facets of physical presence precisely; it only needed to provide superior engagement opportunities compared to traditional video conferencing in hybrid synchronous learning (Bower *et al.*, 2014). Likewise, in Chapter 5, the success of robot Ivy stemmed from its ability to offer consistent, 24/7 companionship—a feature that complemented rather than supplanted human care delivery (Čaić *et al.*, 2018).

The findings suggest that future research and implementation efforts should account for both immediate service interactions and broader ecosystem implications while considering the competitive landscape in which service robots operate (Mahr *et al.*, 2024).

7.3.2. Theme 2: Robot roles and characteristics

Regarding the second overall theme, robot roles and characteristics, this dissertation makes two significant contributions to understanding service robot roles and characteristics. First, it advances service robot literature by redefining augmentation, showing that augmentation extends beyond frontline employees to benefit all actors in service networks. This challenges the provider-centric perspective dominant in existing research and underscores the need for a broader, multi-actor approach. (Huang & Rust, 2018; Phillips *et al.*, 2023, 2025). Second, it empirically identifies a critical relationship between robot autonomy and customization capabilities that shapes how robots transform relationships between human actors across service settings.

Augmentation vs. substitution

This dissertation examined service robots with varying levels of autonomy and customization capabilities performing distinct roles across service settings. The robots ranged from those with relatively medium autonomy and low customization like Amy and Akatar in hospitality (Chapter 2), to Ivy with a similar level of autonomy but higher customization capabilities in healthcare (Chapter 5). Looking at the individual chapters' findings through an ANT - lens (Law & Hassard, 1999), it shows that these characteristics significantly influence how robots transformed relationships between human actors.

For instance, the findings reveal a range of service robot roles in how they *augment* versus *substitute* human capabilities across various constellations of actors. Importantly, this dissertation examines augmentation and substitution at the task level rather than the agent level, recognizing that service robots are implemented within existing constellations of human actors rather than wholly replacing them (De Keyser & Kunz, 2022; De Keyser *et al.*, 2019; McLeay *et al.*, 2021). This nuanced perspective reveals two distinct patterns of robot implementation: robots that substitute specific tasks and roles previously performed by humans (e.g., food delivery in Chapters 2 and 3), and robots that create entirely new service opportunities previously impossible in human-only service delivery (e.g., 24/7 presence of a companion robot in long-term care). While early chapters showed robots primarily augmenting frontline employees in structured tasks (e.g., food delivery in Chapter 2), later chapters demonstrated more nuanced human-robot collaboration. For example, the telepresence robot in Chapter 4 served as an extended self for remote students, facilitating unprecedented opportunities for natural engagement in hybrid settings that traditional video conferencing could not provide (Raes *et al.*, 2020). Similarly, in Chapter 5, robot Ivy enabled 24/7 companionship for healthcare clients - a service dimension that would be impossible for human caregivers to provide consistently (Čaić *et al.*, 2018)

This dissertation also advances understanding of augmentation in service robot literature by expanding its scope beyond the traditional provider perspective. While existing research primarily examines augmentation from the service provider viewpoint - discussing how robots augment FLE capabilities or substitute their tasks (Huang & Rust, 2018; Paluch *et al.*, 2021; Phillips *et al.*, 2023, 2025) - our findings demonstrate that augmentation benefits extend to all actors in the service network. For instance, in Chapter 5, robot Ivy simultaneously augments both healthcare professionals' capabilities to deliver care and clients' abilities to manage their daily routines and social interactions. This multi-actor perspective on augmentation is evident in the shift from FLEs customizing robots on behalf of users (reflecting the traditional provider-centric view of augmentation - "*We use the robot to care for the client"*) toward collaborative customization approaches ("*We use the robot to care together with the client"*. Healthcare clients actively participate in customizing and adapting robot Ivy alongside professionals, effectively co-creating their care experience. This represents a significant advancement in service co-creation (Vargo & Lusch, 2016), as the robot's customization capabilities not only enable new forms of collaboration between service providers and recipients but also demonstrate how service robots can augment the capabilities of all stakeholders, not just service providers. Similarly, Chapter 4's telepresence robot augmented remote students' capabilities to participate in collaborative learning. The same technology could potentially enhance FLEs' abilities to deliver remote instruction, demonstrating that augmentation should be viewed not only from the perspective of FLEs but also from that of customers (De Keyser *et al.*, 2019). This broader conceptualization of augmentation as well as seeing the robot as a vehicle for co-creation between human actors aligns with Actor-Network Theory's emphasis on how technological actors (e.g., service robots) can transform relationships and capabilities across all human actors in the network (Sayes, 2014), not just service providers.

Service robot autonomy and customization

Throughout the investigation of this thesis, the interplay between robot autonomy and customization emerged as a critical factor shaping how service robots transform relationships between human actors across different constellations of actors. The findings reveal that while service robots capable of autonomously executing tasks can reduce the need for human oversight, they often provide fewer opportunities for customization to meet specific user needs. Conversely, robots with lower autonomy typically require greater human involvement for operation and adaptation, offering enhanced customization potential.

This thesis primarily investigated robots with autonomy in execution rather than autonomous decision-making capabilities - reflecting the current state of technology in productive service environments. The focus on real-world implementations through field studies meant that the robots available for investigation were those currently deployed in service settings. These service robots excel at following pre-programmed scripts but have limited artificial intelligence capabilities, such as mechanical, thinking or let alone feeling AI (Huang *et al.*, 2019; Huang & Rust, 2018; 2021). For instance, hospitality robots Amy and Akatar (Chapter 2) demonstrated medium autonomy in executing delivery tasks but offered minimal customization options. In contrast, healthcare robot Ivy (Chapter 5) maintained similar execution autonomy but provided extensive customization capabilities, enabling healthcare professionals and clients to collaboratively adapt the robot's behavior to specific care needs (Čaić *et al.*, 2018; Mahr *et al.*, 2024).

The findings highlight increasing interdependencies in service delivery. Rather than full robot autonomy, this dissertation reveals constellations of humans and robots working together, with success heavily dependent on leveraging customization capabilities and understanding user needs. This suggests that effective service robot implementation requires careful consideration of both technological capabilities and human factors across the service ecosystem (De Keyser & Kunz, 2022).This interplay is particularly evident in Chapter 4, where the telepresence robot's low autonomy preserved human agency - the remote student maintained complete control over the robot's actions. The robot's customization capabilities, particularly its navigational features and adjustable viewpoints, enabled remote students to exercise this autonomy effectively, moving freely through the physical classroom space and adjusting their perspective as needed. By offering these customization options while remaining under human control, the robot effectively augmented remote students' capabilities, transforming traditionally asymmetric remote learning relationships (Williamson *et al.*, 2020) into more equitable and engaging interactions (Chapter 4). This example illustrates how a robot's limited autonomy, combined with rich customization features, can enhance rather than replace human agency, ultimately augmenting users' capabilities in ways that transform relationships between actors in the service network.

Looking ahead, the emergence of more sophisticated AI capabilities in service robots will likely reshape the relationship between autonomy and customization that this thesis has identified - where higher autonomy in task execution often means fewer customization options, and lower autonomy enables greater customization potential. While this trade-off was evident across the studied service robots, the integration of advanced AI capabilities might fundamentally alter this dynamic. As service robots evolve to incorporate autonomous thinking and potentially feeling capabilities (Huang & Rust, 2018, Huang *et al.*, 2019), they could potentially combine high autonomy with extensive customization through their ability to learn from interactions and adapt to user preferences (Huang & Rust, 2021). This evolution raises important questions about accountability and ethics in service delivery (Licardo *et al.*, 2024). For instance, if AI-powered service robots begin making autonomous decisions about care delivery or service customization, how will this affect the relationships and responsibilities between service providers and recipients? Additionally, as robots become capable of more complex social interactions, questions arise about their role in mediating relationships between human and non-human actors and the potential implications for customer and FLE well-being (Phillips *et al.*, 2023, 2025).

7.3.3. Theme 3: Field-first approach - The race strategy

While the previous two themes outlined theoretical contributions regarding actor constellations and relationships between actors within those constellations (7.3.1) and robot roles and characteristics (7.3.2), this section presents three methodological contributions to service robot research. First, it demonstrates how a field-first approach can effectively capture the social complexity and relevance of human-robot interactions that controlled experiments often miss (Lu *et al.*, 2020; Mende *et al.*, 2019, van Doorn *et al.*, 2025). Second, it shows how longitudinal field studies reveal insights about sustained value creation that could not be captured in cross-sectional or laboratory research. Third, it illustrates how letting empirical observations guide theoretical framework selection can lead to richer, more contextually appropriate theoretical insights in service robot research. Together, these methodological contributions complement the theoretical advancements by showing how field research can effectively investigate the complex phenomena described in sections 7.3.1 and 7.3.2.

This dissertation deliberately adopted a field-first approach, prioritizing empirical investigation of real-world implementations. This strategy aligns with van Heerde *et al.*'s (2021) concept of ecological value, emphasizing research that reflects real-world practices and stakeholder needs. The approach responds to calls for more field studies in service robot research (Castelo *et al.*, 2023; Odekerken-Schröder *et al.*, 2022, van Doorn *et al.*, 2025), as controlled experiments often struggle to capture the social complexity surrounding human-robot interaction (Lu *et al.*, 2020).

This thesis evolved from examining single service encounters (Chapters 2 and 3) to increasingly longitudinal investigations. Chapter 4's seven-week study of hybrid classrooms and Chapter 5's two-month implementation analysis provided deeper insights into how human-robot relationships develop over time. This progression revealed that while initial reactions to service robots are important, sustained value creation depends on longer-term adaptation and integration processes.

This field-first strategy enabled the identification of relevant theoretical frameworks based on empirical realities. Rather than starting with theory and searching for applications, we let real-world observations guide our theoretical lens selection (Lynch, 2011). This approach resulted in a dissertation with theoretical diversity across chapters, reflecting the complexity of service robot implementation in different constellations of actors, across various contexts. For instance, in hospitality settings where customer experience was paramount, social presence theory provided valuable insights into human-robot interactions (Chapter 2). In educational contexts, where collaborative learning was central, team learning theory emerged as the most relevant framework (Chapter 4). This theoretical diversity arose organically from the distinct challenges and opportunities observed in each service setting (MacInnis *et al.*, 2020).

The field-first approach enhanced research quality in several ways. By studying service robots in their natural habitat, we captured the authentic interactions between actors that shape technology adoption (De Keyser & Kunz, 2022). For instance, studying collective service experiences with robots in actual hospitality settings revealed social dynamics and collective responses that would have been difficult to capture in laboratory conditions (Morales *et al.*, 2017; Lu *et al.*, 2020). Additionally, by engaging with stakeholders throughout the research process—from professional caregivers to the board of directors of long-term care providers, from technology providers to healthcare insurers (Chapter 6), and from Maastricht University's Centre for Teaching & Learning, EDLAB, and students to study technology-enhanced learning with telepresence robots in hybrid classrooms (Chapter 4)—we ensured that our research addressed real-world challenges and generated actionable insights.

Looking back, this field-first strategy presented certain methodological challenges in balancing rigor with realism. Van Doorn *et al.* (2025, p.3) refer to this as the *data dilemma*, where service robot researchers often face a tension between rigor and relevance. Research teams with access to robots frequently struggle to apply rigorous methods, while teams skilled in research methodology tend to rely on non-field data, as controlled lab studies minimize noise and allow for cleaner application of methodological techniques. This dissertation directly addressed this challenge by combining field access to service robots with rigorous mixed-methods approaches across multiple service settings. While Van Doorn *et al.* (2025) observe that robot commercialization often stalls at the pilot stage, hindering data collection and broader implementation, this research succeeded in studying sustained use through longitudinal field studies (Chapters 4 and 5) and ecosystem-level implementation (Chapter 6). The methodological challenges were ultimately outweighed by the benefits of producing research that captures how service robots transform relationships between human actors across diverse constellations of actors across various service settings. As emphasized in the introduction, this approach helped avoid the pitfalls of studying service robots in isolation from the social complexity that determines their adoption and impact in real-world service settings.

7.3.4. Future research

Building upon the findings, theoretical and methodological contributions presented in this dissertation, several critical areas deserve further investigation. These research opportunities, visualized in **Figure 7.1**, align with the three overarching themes of: actor constellations *beyond the dyad*, robot roles and characteristics, and methodological approaches to studying service robots in the field.

First, regarding actor constellations, the observed progression from triadic relationships through different types of constellations of actors (e.g., groups of customers, hybrid teams of users) to broader multi-level ecosystem perspectives warrants deeper exploration, particularly regarding how service robots transform relationships between human actors across different levels of service ecosystems.

Second, concerning robot roles and characteristics, our findings on augmentation versus substitution reveal the need to better understand how service robots can simultaneously serve different types of actors (i.e., customers and FLEs) while adapting to their unique needs and capabilities. The observation that robots can perform different roles for different actor groups - serving as a tool for some while acting as a companion for others - warrants deeper investigation into how these dual roles can be optimally designed and managed. Importantly, while existing research primarily examines augmentation from the service provider viewpoint (Huang & Rust, 2018; Paluch *et al.*, 2022, Phillips *et al.*, 2023, 2025), our findings demonstrate that augmentation benefits extend to all actors in the service network. For instance, in healthcare settings, robot Ivy simultaneously augments both healthcare professionals' capabilities to deliver care and clients' abilities to manage their daily routines. This broader conceptualization of augmentation as extending beyond FLEs to include customers opens new research possibilities.

Third, a striking pattern emerged across the studied service robots - those with higher autonomy in task execution often offered fewer customization options, while those with lower autonomy enabled greater customization potential. For instance, hospitality robots (Chapters 2 and 3) demonstrated medium autonomy in executing delivery tasks but offered minimal customization options, while healthcare robot Ivy (Chapter 5) maintained similar execution autonomy but provided extensive customization capabilities. This apparent trade-off between autonomy and customization capabilities warrants deeper investigation. Understanding whether this relationship is inherent to current technological limitations or a design choice, and how it affects value creation for different actor groups, could provide crucial insights for future service robot development and implementation.

Fourth, while this dissertation identified a trade-off between autonomy and customization in service robots that primarily execute pre-programmed scripts, this relationship may fundamentally change as robots evolve to incorporate more sophisticated AI capabilities (Huang & Rust, 2018). The current trade-off - where higher autonomy in task execution often means fewer customization options - emerged from studying robots with autonomy in execution rather than decision-making. However, as service robots advance to incorporate autonomous thinking and feeling capabilities (Becker *et al.*, 2022; Huang & Rust, 2021), they could potentially combine high autonomy with extensive customization through their ability to learn from interactions and adapt to user preferences. This evolution beyond scripted execution to AI-powered autonomous decision-making raises important questions about accountability and ethics in service delivery (Licardo *et al.*, 2024). For instance, if AI-enabled service robots begin making autonomous decisions about service customization, how will this affect relationships and responsibilities between service providers and recipients? Such questions become particularly relevant as robots transition from executing pre-programmed tasks to making autonomous decisions about how to customize and deliver services.

Finally, regarding methodological approaches, the field-first approach adopted in this dissertation highlights the need for methodological innovations that can capture the social complexity surrounding human-robot interaction while maintaining research validity. Future research should explore how to balance rigor and relevance in service robot studies, particularly given the challenges identified by Van Doorn *et al.* (2025) regarding the tension between access to field data and methodological sophistication.

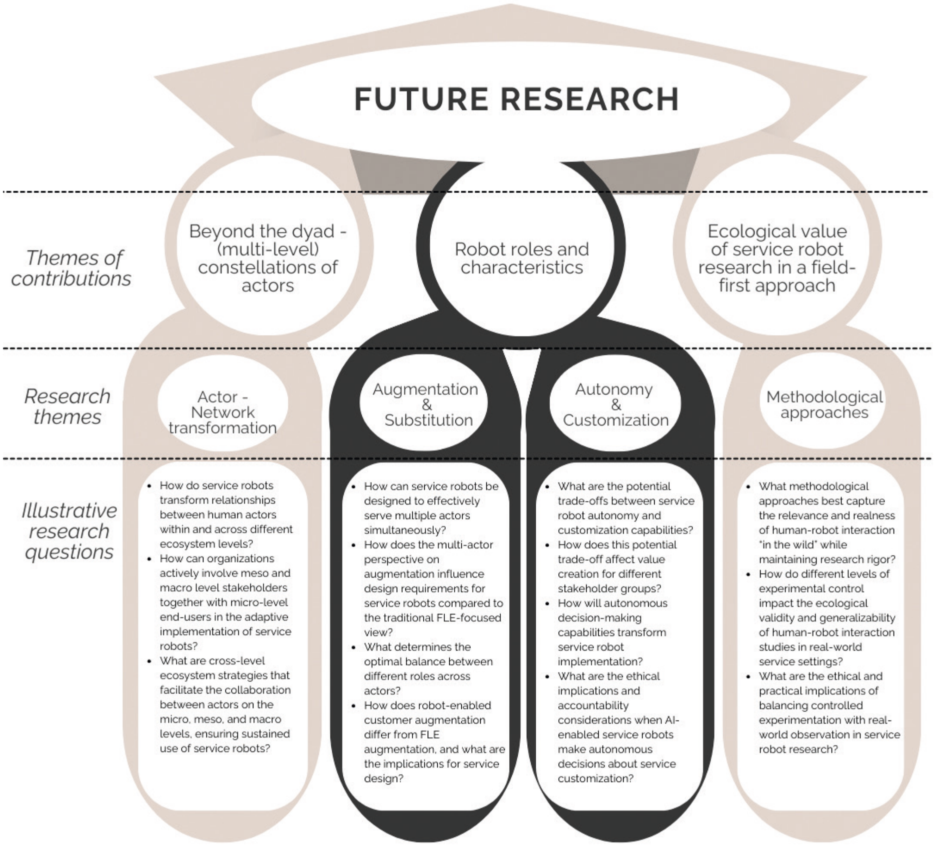

Figure 7.1. Future research, overarching themes of contributions, research themes and future research question

7.4. STEERING THE COURSE - MANAGERIAL IMPLICATIONS

While the previous sections outlined theoretical contributions and suggestions for future research, this dissertation also provides practical implications for service organizations implementing service robots. While detailed, context-specific managerial implications can be found in each individual chapter, this section synthesizes overarching implications that emerge from examining the dissertation as a whole. These implications align with our research question: *How do the roles and characteristics of service robots affect various constellations and relationships (human and non-human) in real-world service settings?* They are presented in three main themes: actor constellations, robot roles and characteristics, and implementation approaches.

First, regarding actor constellations, this dissertation demonstrates that service organizations must move beyond viewing robot implementation as a series of isolated dyadic interactions. Instead, managers need to recognize that service robots are implemented within complex networks of human actors, where HRIs influence and transform existing relationships between actors. For instance, in hospitality settings, successful implementation requires understanding how robots affect not just individual customer interactions, but group dynamics and frontline employee relationships (Chapter 2 & Chapter 3). In Chapter 2, we found that high-quality frontline employee interactions can compensate for lower utilitarian value of service robots like Amy and Akatar, suggesting managers should strategically deploy human staff alongside robots during initial implementation phases. Chapter 3 revealed that customers in groups collectively make sense of robot encounters, developing shared realities that significantly influence post-purchase outcomes. This finding suggests restaurant managers should facilitate positive collective experiences around service robots like Relay and LuckiBot by creating opportunities for shared customer interaction rather than focusing solely on individual customer-robot exchanges (Steins *et al.*, 2024). In education settings, managers must consider how robots can transform traditionally asymmetric relationships in hybrid teams of remote and on-site students into more equitable and engaging interactions (Chapter 4). Specifically, telepresence robot TEMI enhanced remote students' presence through physical embodiment and mobility, fostering more natural interactions compared to traditional video conferencing. Educational institutions should therefore design learning spaces to maximize robot mobility and presence-enhancing capabilities, ensuring wide aisles and accessible seating arrangements that accommodate robot navigation. Similarly, in healthcare settings, robot implementation strategies must consider how robots simultaneously serve and influence relationships between healthcare professionals, clients, and informal caregivers. For example, Chapter 5 demonstrated that social robot Ivy created distinct value for both people with intellectual disabilities (improved daily structure and emotional well-being) and healthcare professionals (reduced workload and enhanced care quality). This dual value creation requires healthcare managers to carefully select implementation cases based on both client characteristics and staff capabilities, rather than focusing on just one stakeholder group. This network perspective demands implementation strategies that coordinate activities and align resources across organizational levels, from frontline service delivery to organizational support systems (Chapter 5 & 6).

Second, concerning robot roles and characteristics, organizations face crucial decisions about how robots could and should augment or substitute human capabilities. The findings reveal that these decisions should be based not only on technological capabilities but also on user needs and the potential for value creation across actor groups. Particularly important is the identified trade-off between robot autonomy and customization capabilities. In Chapter 2, hospitality robots Amy and Akatar demonstrated medium autonomy in executing delivery tasks but offered minimal customization options. The findings showed that when these robots exhibited high utilitarian value (consistent and accurate service delivery), they could potentially substitute certain frontline employee tasks, reducing the need for customer-employee interactions (Odekerken-Schröder *et al.*, 2022). Consequently, hospitality managers should consider deploying more autonomous robots, which could have an even greater substitution potential, as the involvement of employees may not be necessary at all times. Based on the findings of this thesis, this is particularly relevant for repetitive, standardized tasks. Service organizations must carefully weigh whether to implement highly autonomous robots that improve operational efficiency but offer limited customization, or lower autonomy robots that require more human involvement but enable greater adaptation to specific user needs.

In long-term care, for example, organizations can deploy highly autonomous robots for routine tasks like meal delivery and room sanitization, while using lower-autonomy robots for personalized companionship and positive affirmation, ensuring a balance between efficiency and personalized care. Moreover, organizations should leverage robots' ability to simultaneously serve multiple groups of actors, as demonstrated by healthcare robot Ivy's dual role in supporting both professional caregivers' work efficiency and clients' independence (Chapter 5 & Chapter 6). Specifically, Ivy maintained medium execution autonomy while providing extensive customization capabilities, enabling healthcare professionals and clients to collaboratively adapt the robot's behavior to specific care needs. Healthcare organizations should therefore invest in robots with robust customization interfaces that allow both staff and clients to participate in programming, thereby facilitating co-creation of care experiences (Čaić *et al.*, 2018; Mahr *et al.*, 2024).

Third, the findings provide clear guidance for implementation approaches. Organizations should adopt a systematic yet flexible implementation process that recognizes the distinction between initial acceptance and sustained use of service robots. This process should include robust stakeholder training and support systems, particularly during early implementation phases when adaptation processes are crucial. Chapter 5 revealed that healthcare organizations successfully implementing robot Ivy provided systematic team training and shared learning opportunities for healthcare professionals, allocating dedicated programming time for robot setup and maintenance. Those organizations that failed to provide this support experienced higher discontinuation rates, with insufficient time for programming emerging as a key barrier to sustained use. Regular assessment of both barriers (categorized as deal-breakers, obstacles, or minor hurdles) and facilitators (key drivers, enablers, or minor boosters) enables organizations to proactively address implementation challenges (Chapter 5). Findings from chapter 5 show that sustained use of service robots requires continuous adaptation as the purpose for use (e.g., functional vs. social) changes over time based upon user needs, preferences as well as contextual factors that influence how robots can be used.

Moreover, as demonstrated in Chapter 6, successful implementation often requires ecosystem-level innovation that spans micro (user), meso (organizational), and macro (societal) levels. For instance, implementing Service Robot-based Innovation for Public Value in healthcare required coordination across these levels, with a national healthcare insurer serving as an orchestrator guiding ecosystem development. Organizations should therefore identify and engage all relevant stakeholders early in the implementation process—from healthcare service providers to users, technology suppliers and research institutions—to align goals and share expertise (Mahr *et al.*, 2024). This implies that for successful robot implementation organizations must coordinate activities not only internally but also with external stakeholders. This is particularly crucial when implementing service robots to address societal challenges, such as workforce shortages in healthcare, where success depends on aligning public and private stakeholder activities and resources to create sustainable Public Value. Furthermore, organizations must design implementation processes that can adapt to user feedback and evolving needs, ensuring that robot deployment creates sustained value for all actors involved.

These managerial implications extend beyond individual service settings to provide broader guidance for organizations implementing service robots across industries. By considering actor constellations, carefully selecting robot roles and characteristics, and adopting systematic implementation approaches, organizations can better navigate the complexities of service robot implementation within different constellations of human actors.

7.5. IMPACT STATEMENT: ADVANCING KNOWLEDGE BASED ON REAL-WORLD IMPLEMENTATION

Service robots are increasingly appearing across various industries - from delivering food in restaurants to enabling remote students to participate in classroom education and supporting patients in healthcare settings. While these robots promise to address growing workforce shortages and enhance service experiences, their successful implementation requires understanding how they interact with and transform relationships between humans in real-world service settings. This doctoral research investigated how different types of physically embodied service robots create value within diverse constellations of human actors across hospitality, education, and healthcare environments. When considering long-term impact, this dissertation follows Haenlein and Jack's (2025) conceptualization focusing on three key elements: *rigor* (methodological and theoretical precision ensuring validity and reliability of findings), *relevance* (addressing significant real-world issues providing insights that meaningfully change stakeholder behavior), and *resonance* (how well the research connects with and reaches its intended audience). This research strives to balance these elements by combining methodological thoroughness through field studies with practical insights for diverse stakeholders across service settings.

7.5.1. Scientific impact

This research provides several important scientific contributions that advance our understanding of service robot implementation. First, by examining increasingly complex constellations of human actors interacting with robots—from triadic relationships (Chapter 2) to collective customer experiences (Chapter 3) in hospitality settings, and hybrid team interactions in higher education (Chapter 4), extending to complex triadic relationships (Chapter 5) and broader ecosystem-level implementations (Chapter 6) in healthcare—this thesis moves beyond the traditional focus on isolated dyadic robot-user interactions that has dominated existing research (Abboud et al., 2021; van Doorn et al., 2025). This expanded perspective reveals how service robots transform relationships between humans rather than simply replacing them, offering deeper insights into the social complexity surrounding human-robot interaction in service settings. For example, Chapter 3 reveals how customers in groups collectively make sense of robot encounters, developing shared realities that significantly influence post-purchase outcomes like switching intentions and relational well-being, showing that restaurant managers should focus on facilitating positive collective experiences rather than merely individual interactions.

Second, the research introduces novel frameworks for understanding how robot characteristics—particularly their levels of autonomy and customization capabilities—influence their ability to create value for different stakeholders. For instance, the findings reveal that robots with lower autonomy often enable greater customization potential, which can be particularly valuable in healthcare settings where adapting to individual client needs is essential as demonstrated with robot Ivy in long-term care (Chapter 5). Conversely, more autonomous robots with limited customization options may be better suited for standardized tasks in hospitality environments as shown with robots Amy, Akatar and LuckiBot in restaurant settings (Chapters 2 and 3). This nuanced understanding helps bridge technological and service perspectives on robot implementation beyond current frameworks (Huang & Rust, 2021; Wirtz et al., 2018). For instance, Chapter 5 demonstrates that robot Ivy creates specific value for clients through personalized reminders and companionship that is possible because healthcare professionals can extensively customize the robot's interactions to address each client's unique needs and daily routines. As service robots evolve to incorporate more sophisticated AI capabilities, this apparent trade-off between autonomy and customization may fundamentally change, enabling future robots to potentially combine high autonomy with extensive personalization through their ability to learn from interactions and adapt to user preferences (Chapter 7).

Third, the field-based methodology employed throughout this research captures authentic interactions that laboratory studies cannot replicate. By studying robots "in the wild" across multiple service settings, this research provides ecological validity that enhances the applicability of findings to real-world implementation challenges as advocated by van Heerde et al. (2021) and van Doorn et al. (2025). For example, Chapter 4's longitudinal seven-week study of telepresence robots in 17 tutorial groups revealed temporal effects that would be impossible to observe in lab studies, showing that these robots are particularly valuable during the early, formative stages of group development when establishing psychological safety and social cohesion is crucial. This approach responds directly to calls within the literature for more field studies on service robots (De Keyser & Kunz, 2022; Lu et al., 2020), demonstrating how researchers can balance methodological rigor with practical relevance.

7.5.2. Societal impact

Beyond its scientific contributions, this research offers significant societal impact across several domains. Most immediately, it provides practical guidance for organizations implementing service robots to address workforce shortages in labor-intensive service industries. The findings demonstrate that robots can both augment and substitute certain human tasks, enabling more efficient resource allocation while potentially enhancing service quality. For instance, in hospitality settings, robots can deliver food and drinks, freeing staff to focus on more complex, value-adding customer interactions (Chapter 2). Specifically, Chapter 2 reveals that when hospitality robots like Amy and Akatar demonstrate high utilitarian value (i.e., consistent, and accurate service delivery), they can effectively substitute certain frontline employee tasks, allowing restaurants to maintain service levels with fewer staff members during labor shortages, while human staff can mitigate mistakes made by service robots.

For healthcare organizations facing critical staffing challenges, this research offers particularly valuable insights. The findings show that social robots can provide 24/7 cognitive support and companionship for people with intellectual disabilities, while simultaneously reducing the emotional and workload burden on healthcare professionals (Chapter 5). For example, Chapter 5 identifies specific implementation facilitators—such as matching robot capabilities with client needs and providing dedicated programming time for healthcare professionals—that resulted in successful, sustained robot use in 63% of cases across six healthcare organizations, offering insights to develop a practical blueprint for scaling up robot implementation. By identifying factors that influence successful implementation—from client characteristics to organizational support structures—this research helps healthcare providers make more informed decisions about robot deployment, potentially improving both care quality and staff well-being in resource-constrained environments.

In educational settings, the research demonstrates how telepresence robots can create more inclusive learning environments by enabling remote students to participate more naturally and equitably in collaborative activities (Chapter 4). Specifically, telepresence robot TEMI enhanced remote students' presence through physical embodiment and mobility, fostering more natural interactions compared to traditional video conferencing, with remote students being perceived as more engaged and valuable contributors by their on-site peers. As educational institutions increasingly adopt hybrid learning models, these insights can help create more engaging experiences for all students, regardless of their physical location.

Finally, this research contributes to broader societal discussions about human-robot collaboration by moving beyond simplistic narratives of robot-driven job displacement. Instead, it demonstrates how robots can transform—rather than simply replace—human relationships and activities across service settings (Chapters 2-6). For example, Chapter 6 illustrates how a Public Value Innovation ecosystem in healthcare enabled stakeholders from public and private sectors to collaboratively develop and implement robot Ivy across multiple long-term care organizations, providing a model for cross-sector collaboration to address workforce challenges. This more nuanced perspective can inform policy discussions and organizational strategies around technological adoption, helping to ensure that service robots enhance rather than diminish human experiences and capabilities.

7.5.3. Target audiences and knowledge dissemeniation

This research offers valuable insights for several key audiences. Service organizations across hospitality, healthcare, and education can apply the findings to make more informed decisions about robot selection and implementation strategies. Technology developers can use the insights about robot characteristics and their impact on human relationships to design more effective service robots. Policymakers concerned with workforce development and service quality can leverage this research to develop more nuanced regulatory approaches that balance innovation with human well-being.

To maximize impact, the knowledge generated through this research has been disseminated through academic publications (Chapters 2, 3, and 6 have been published and Chapters 4, and 5 are under review in top-tier journals), industry collaborations, and educational activities. Beyond traditional academic channels, the practical frameworks and implementation guidelines developed through this research can be translated into accessible toolkits and training materials for service organizations. For instance, the classifications of implementation facilitators and barriers in Chapter 5—categorized as key drivers, enablers, and minor boosters versus deal-breakers, obstacles, and minor hurdles—provide organizations with a practical assessment framework to evaluate and address implementation challenges before they arise. Additionally, the field-based approach employed across all empirical chapters (Chapters 2-5) demonstrates the value of academic-industry partnerships in generating knowledge that is both scientifically rigorous and practically relevant. This approach aligns with Haenlein and Jack's (2025) emphasis on achieving resonance by ensuring research findings reach and influence intended audiences. By communicating findings through both academic publications and accessible formats for practitioners, this research maximizes its potential for both scientific impact (changing academic perspectives) and societal impact (changing organizational practices), enhancing the overall return on research investment and maximizing long-term impact.

By enhancing our understanding of how service robots transform relationships between human actors across service settings, this research ultimately contributes to developing more effective, sustainable approaches to technological innovation in services—approaches that create value not just through operational efficiency but through enhanced experiences for all stakeholders involved.

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SUMMARY

A RECAP OF THE TOUR

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Service robots are increasingly deployed across industries to address workforce challenges and enhance service delivery. However, successful implementation requires understanding of how different types of robots interact with and influence relationships between human actors in service settings. This dissertation investigates how physically embodied service robots, varying in their levels of autonomy and customization capabilities, create value across diverse constellations of actors in real-world service environments. Through field studies in hospitality (Chapters 2 and 3), higher education (Chapter 4), and healthcare settings (Chapters 5 and 6), this research moves beyond traditional dyadic perspectives to examine increasingly complex constellations of actors. The findings reveal how service robots transform relationships between human actors across different service contexts - from augmenting or substituting frontline employees in hospitality triads (Chapter 2), to facilitating collective customer experiences (Chapter 3), enabling equitable participation in hybrid education teams (Chapter 4), and supporting healthcare professionals and clients in long-term care settings (Chapters 5 & 6). This dissertation demonstrates that successful service robot implementation requires careful consideration of both immediate service interactions and broader ecosystem implications. By adopting an Actor-Network Theory perspective, the research shows how service robots, as non-human actors, actively shape service delivery by transforming relationships between human actors across micro, meso, and macro levels of service ecosystems. The findings provide theoretical contributions to service robot literature while offering practical guidance for organizations implementing robots across industries.

SAMENVATTING

EEN TERUGBLIK OP DE TOUR

SAMENVATTING – EEN TERUGBLIK OP DE TOUR

Service robots worden steeds vaker gebruikt in sectoren zoals horeca, onderwijs en zorg. Ze helpen om personeelstekorten op te vangen en de dienstverlening te verbeteren. Maar om deze robots goed in te zetten, is het belangrijk te begrijpen hoe ze samenwerken met mensen en hoe ze de relaties tussen mensen (medewerkers, klanten, cliënten, etc.) veranderen. In dit proefschrift wordt onderzocht hoe fysiek belichaamde service robots – die verschillen in hoe zelfstandig en aanpasbaar ze zijn – waarde kunnen toevoegen in de praktijk. Via veldonderzoek in horeca (Hoofdstukken 2 en 3), het hoger onderwijs (Hoofdstuk 4) en de gezondheidszorg (Hoofdstukken 5 en 6) gaat dit onderzoek verder dan traditionele één-op-één interacties, om steeds complexere netwerken van betrokkenen te bestuderen. De resultaten laten zien hoe service robots diverse rollen aannemen en menselijke relaties veranderen in verschillende dienstverleningscontexten: van het ondersteunen of deels vervangen van medewerkers in restaurants (Hoofdstuk 2), tot het bevorderen van gezamenlijke klantervaringen (Hoofdstuk 3), het verbeteren van deelname in hybride onderwijsgroepen (met fysiek aanwezige én online studenten; Hoofdstuk 4), en het assisteren van zorgprofessionals en cliënten in de langdurige zorg (Hoofdstukken 5 & 6).

Dit proefschrift toont aan dat succesvolle implementatie van service robots zorgvuldige overwegingen vereist van zowel directe dienstverleningsinteracties als bredere ecosysteemimplicaties. Door een Actor-Netwerk Theorie perspectief te hanteren, laat het onderzoek zien hoe service robots, als niet-menselijke actoren, actief de dienstverlening vormgeven door relaties tussen mensen te veranderen op individueel niveau, organisatieniveau en maatschappelijk niveau. De bevindingen dragen bij aan de wetenschappelijke kennis over service robots en bieden praktische handvatten voor organisaties die robots willen implementeren in verschillende sectoren.

ABOUT THE AUTHOR

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Mark Steins was born in Geleen, the Netherlands, on the 15th of January, 1989. He holds a Master of Science in International Business with a specialization in Organization: Management, Consultancy & Change from Maastricht University (graduated cum laude in 2012), and a Bachelor in Business Administration with a focus on People & Business Management from Zuyd University, Sittard, the Netherlands.

Prior to embarking on his dual PhD program between Maastricht University and Queensland University of Technology in 2021, Mark gained valuable industry experience as a project manager, consultant, and training specialist in marketing and digital innovation management. Moreover, Mark joined the Marketing and Supply Chain Management department at Maastricht University SBE as a lecturer in 2016 and gained valuable teaching and executive teaching experience internationally. During his time as a lecturer, Mark also held a part-time position at the Service Science Factory – Maastricht University (now UMIO Innovate) as a service designer. This blend of academic and practical expertise informs his field-first approach to research, which focuses on service robots, service ecosystems, and technology infusion in transformative settings like education and healthcare.

Mark completed most of his PhD in The Netherlands and moved to Brisbane in October 2023. His PhD was completed under the supervision of Professor Dr. Gaby Odekerken-Schröder, Professor Dr. Dominik Mahr, Dr. Frank Mathmann and Professor Dr. Rebekah Russell-Bennett. Next to his research and teaching activities, Mark is a co-founding member of the Maastricht Center for Robots, a knowledge institute aiming to create impact with service robot related research and education in collaboration with industry partners.

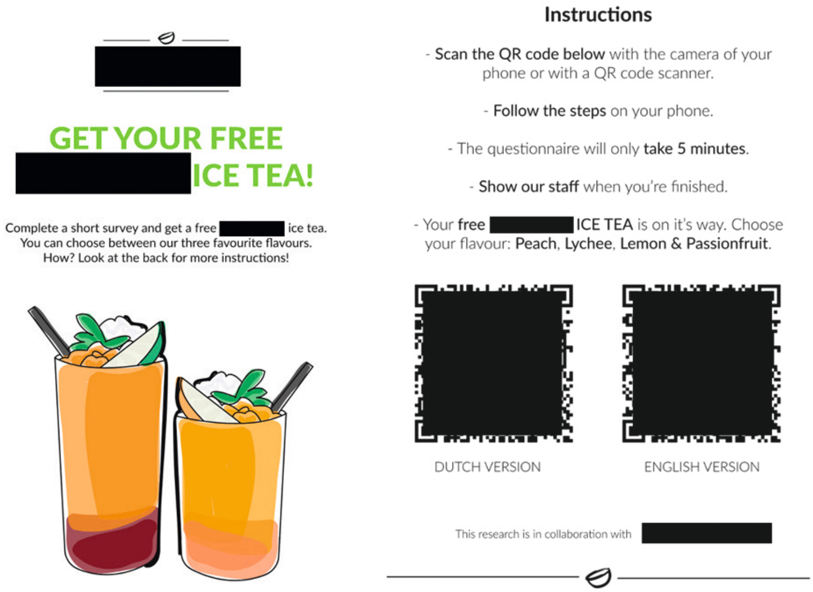
Mark's research has been recognized with multiple awards, including the Robert Johnston Award for Best Paper in the Journal of Service Management and an Outstanding Paper Award from Emerald Publishing. In addition to the publications included in this dissertation, Mark co-authored multiple published papers during his PhD trajectory. His work has been published in leading journals including the Journal of Service Research, the Journal of Product Innovation Management, the Journal of Business Research, the Journal of Service Management, and the Journal of Services Marketing.

APPENDICES

APPENDICES

Chapter 2

A2.1. Anonymized flyer containing QR-code



A2.2. Scenario descriptions study 2

Hedonic Value		High	High	Low	Low
Utilitarian Value		High	Low	High	Low
FLE Interaction	High	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. The human employees are very helpful and how they interact with you and your company is excellent.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. The human employees are very helpful and how they interact with you and your company is excellent.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. The human employees are very helpful and how they interact with you and your company is excellent.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. The human employees are very helpful and how they interact with you and your company is excellent.

A2.2. Scenario descriptions study 2

Hedonic Value	High	High	Low	Low
Utilitarian Value	High	Low	High	Low
Low	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. The human employees are not helpful and how they interact with you and your company is horrible.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. The human employees are not helpful and how they interact with you and your company is horrible.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. The human employees are not helpful and how they interact with you and your company is horrible.	While you are sitting at your table, you are being served by the robot Akatar and human employees. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. The human employees are not helpful and how they interact with you and your company is horrible.

A2.2. Scenario descriptions study 2

Hedonic Value	High	High	Low	Low
Utilitarian Value	High	Low	High	Low
No	While you are sitting at your table, you are being served by the robot Akatar. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. You have not interacted with any of the human employees and were only served by the robot Akatar.	While you are sitting at your table, you are being served by the robot Akatar. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar brings fun, for example, it makes jokes. It is also entertaining, for example, it poses for pictures. It makes the interaction with the robot Akatar very enjoyable. You have not interacted with any of the human employees and were only served by the robot Akatar.	While you are sitting at your table, you are being served by the robot Akatar. The robot Akatar takes your orders and serves your drinks and food in a highly consistent and very accurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. You have not interacted with any of the human employees and were only served by the robot Akatar.	While you are sitting at your table, you are being served by the robot Akatar. The robot Akatar takes your orders and serves your drinks and food in a highly inconsistent and very inaccurate manner. While serving drinks and food, the robot Akatar does not bring fun, for example, it does not make jokes. It is neither entertaining, for example, it does not pose for pictures. It makes the interaction with the robot Akatar very unenjoyable. You have not interacted with any of the human employees and were only served by the robot Akatar.

Chapter 3

A3.1. Rationale coding scheme

In line with Lazarus and Folkman (1984), we coded a review as showing a *threat appraisal* if it clearly indicated a negative situation, for example involving negative perceptions of the robot, fear, or disappointment, and as a *challenge appraisal* if it described positive perceptions of the robot, excitement, or affection. Based on the same work (i.e., Lazarus & Folkman, 1984), we coded a review as representing *problem-focused coping* if it clearly showed an action in response to the appraisal and as representing *emotion-focused coping* if the customers clearly expressed dealing with their emotions. Reviews that showed how customers consulted others about their interactions with the robot were coded as *social support seeking* (Folkman *et al.*, 1986). Relational service well-being was coded in line with the conceptualization by Falter and Hadwich (2020), switching intention with that by Keaveney (1995), repurchase (intention) in line with Hellier *et al.* (2003), and word-of-mouth based on Babin *et al.* (2005). Lastly, reviews were classified as describing a *collective service experience* if they clearly showed that multiple customers experienced the service collectively, by referring for instance to 'we', or 'my husband' and as describing a *shared reality* if it became apparent that customers developed a common understanding of the situation (Rossignac-Milon *et al.*, 2021).

A3.2. Informational Flyer, Study 2

A3.3. Voucher QR Code, Study 2

SURVEY VOUCHER

1: Scan de QR-code om naar de enquête in uw voorkeurstaal te gaan.
2: Volg de stappen op uw smartphone.
3: Het invullen van de enquête duurt **±3 minuten**. U heeft de unieke vouchercode (bijv. DADAxxxx) nodig om de enquête te starten.
4: Retourneer uw voucher wanneer u aan de kassa betaalt en ontvang een verrassingsgeschenk.

1: Scannen Sie den QR-Code um zur Umfrage in Ihrer bevorzugten Sprache zu gelangen.
2: Befolgen Sie die Schritte auf Ihrem Smartphone.
3: Die Umfrage dauert **±3 Minuten.** Zu Beginn der Umfrage müssen Sie Ihren Gutscheincode (z. B. DADAxxxx) eingeben.
4: Tauschen Sie Ihren Gutschein beim Bezahlen gegen ein Überraschungsgeschenk ein.

1: Scan the QR code to go to the survey in your preferred language.
2: Follow the steps on your smartphone.
3: The survey takes **±3 minutes.** You need the unique voucher code (e.g. DADAxxxx) to start the survey.
4: Return your voucher upon check-out and exchange it for a surprise gift.

A3.4. Study 2. Measurement model: validity and reliability & results of hypotheses testing

To ensure construct reliability, we examined the item loadings, composite reliabilities, and Cronbach's alphas. With the exception of the first item of the switching intention construct (factor loading of .67, near the commonly accepted threshold of .70; Hair *et al.*, 2016), all items demonstrate factor loadings that exceed the threshold (Table 1). For each construct, the composite reliability values are above the threshold of .6 (Hair *et al.*, 2017a), as are the Cronbach's alpha values, with the exception of social support seeking (.57). Because Cronbach's alpha is a less precise measure of reliability (Hair *et al.*, 2019) and composite reliability values exceed (.82–.90) the well-established threshold, the results offer support for internal consistency and reliability.

The average variance extracted (AVE) values for all constructs indicate high levels of convergent validity (Hair *et al.*, 2016, 2019) with values well above .50 (Table 2). To ensure discriminant validity, the square root of the AVE of each construct should be higher than its correlations with other constructs and not lower than .7 (Chin, 1998; Fornell & Larcker, 1981; Hair *et al.*, 2019). All constructs meet these criteria (Table 2). Finally, multicollinearity is not a threat, because all the VIF fall below 5 (Hair *et al.*, 2019) and even below the more conservative threshold level of 3 (Becker *et al.*, 2015).

To evaluate the model's predictive relevance, we examine the effect sizes and explained variance of the endogenous constructs. The R^2 values of the endogenous constructs (Table 3) exceed the 0.1 threshold, which, following Hair *et al.* (2019) is deemed satisfactory, especially considering the contextual specifics of our study. Moreover, the effect sizes for the hypotheses that received support range from .02 to .15, indicating small to medium effects (Hair *et al.*, 2016, 2019), thereby affirming the model's predictive relevance.

Table 1. *Constructs, items, and factor loadings*

Construct (Sources)	Items	Standardized Loadings
Appraisal		
Challenge (Duhachek & Iacobucci, 2005; Peacock & Wong, 1990)	Being served by the robot...	
	(1) ... had a positive impact on my restaurant experience.	.835
	(2) ... made me eager to interact with the robot.	.770
	(3) ... made me excited.	.702
	(4) ... made me enthusiastic.	.836
Threat (Duhachek & Iacobucci, 2005; Peacock & Wong, 1990)	Being served by the robot...	
	(1) ... was a threatening situation for me.	.762
	(2) ... made me anxious.	.798
	(3) ... had a negative impact on my restaurant experience.	.848
	(4) ... made me upset.	.802
Coping strategies		
Problem-focused coping (Duhachek, 2005)	The following statements are about today's experience of being served by the robot.	
	(1) I concentrated on how to solve problems related to being served by the robot.	.725
	(2) I thought about how to handle being served by the robot.	.842
	(3) I concentrated my efforts on dealing with being served by the robot.	.758
Emotion-focused coping (Duhachek, 2005)	The following statements are about today's experience of being served by the robot.	
	(1) I took time to express my emotions about being served by the robot.	.843
	(2) I let my feelings about being served by the robot out somehow.	.851
	(3) I validated and justified my feelings about being served by the robot.	.751
Social support seeking (Folkman *et al.*, 1986)	The following statements are about today's experience of being served by the robot.	
	(1) I talked to someone at my table to find out more about being served by the robot.	.760
	(2) I talked to someone at my table about how I was feeling about being served by the robot.	.899
Shared reality		

Table 1. *Continued*

Construct (Sources)	Items	Standardized Loadings
Shared reality (Rossignac-Milon *et al.*, 2021)	During the restaurant visit, the people at my table…	
	(1) … developed a joint perspective about the robot.	.820
	(2) … shared the same thoughts and feelings about the robot.	.886
	(3) … thought about the robot in a more and more similar way.	.803
	(4) … saw the robot in the same way.	.804
Post-purchase outcomes related to the service (provider)		
Relational service well-being (Falter & Hadwich, 2020)	Please indicate your agreement with following statements	
	(1) I trust this restaurant.	.835
	(2) During the restaurant visit, I feel that I am taken seriously.	.839
	(3) During the restaurant visit, I am treated fairly.	.767
Switching intention (Tsarenk & Tojib, 2012)	Please indicate your agreement with following statements	
	(1) I will spend less money at this restaurant in the future.	.666
	(2) I will reduce frequency of coming to this restaurant.	.819
	(3) I will switch to other restaurants.	.834

Table 2. *Means, standard deviations, correlations, and reliability estimates*

Construct	Mean	SD	AVE	CR	α	1	2	3	4	5	6	7	8
Challenge Appraisal	4.73	1.34	.621	.867	.794	*.788*							
Threat Appraisal	1.55	.92	.645	.879	.825	-.495	*.803*						
Problem focused coping	3.39	1.43	.604	.820	.676	.290	-.085	*.777*					
Emotion focused coping	3.08	1.60	.666	.857	.749	.320	-.011	.524	*.816*				
Social Support Seeking	3.89	1.63	.693	.818	.570	.335	-.186	.556	.551	*.832*			
Shared Reality	5.10	1.27	.688	.898	.848	.481	-.278	.263	.323	.318	*.829*		
Relational service well-being	5.99	.79	.663	.855	.750	.356	-.383	.163	.158	.228	.327	*.814*	
Switching intention	2.29	1.05	.603	.819	.678	-.268	.264	-.106	-.143	-.1338	-.250	-.507	*.777*

Notes: All constructs were measured on seven-point interval scales; SD = standard deviation; AVE = average variance extracted; CR = composite reliability; α = Cronbach's alpha. The square root of the average variance extracted for each construct is indicated in italics on the diagonal of the correlation matrix.

Table 3. *Results of hypotheses testing and explained variance*

Hypothesized Relationship	Standard Path Coefficient (*p*-Value)	Hypothesis Results	R^2 (construct)
H1: Challenge appraisal → Outcomes			
H1a: Relational service well-being	.115 (.094)	NS	
H1b: Switching intention	-.092 (.208)	NS	
H2: Threat appraisal → Outcomes		S	
H2a: Relational service well-being	-.258 (.000)	S	.107 (Problem-focused coping)
H2b: Switching intention	.158 (.018)		
H3: Challenge appraisal → Coping strategies	.335 (.000)	S	.156 (Emotion-focused coping)
H3a: Problem-focused coping	.424 (.000)	S	.164 (Social support seeking)
H3b: Emotion-focused coping	.332 (.000)	S	
H3c: Social Support seeking			
H4: Threat appraisal → Coping strategies			.153 (Shared reality)
H4a: Problem-focused coping	.080 (.148)	NS	
H4b: Emotion-focused coping	.197 (.007)	S	
H4c: Social Support seeking	-.024 (.706)	NS	
H5: Coping strategies → Shared reality			.260 (Relational service well-being)
H5a: Problem-focused coping	.060 (.318)	NS	
H5b: Emotion-focused coping	.201 (.007)	S	.173 (Switching intention)
H5c: Social Support seeking	.178 (.012)	S	
H6: Shared reality → Outcomes			
H6a: Relational service well-being	.187 (.003)	S	
H6b: Switching intention	-.148 (.019)	S	

Notes: NS = not supported, S = supported.