User Experience of Social Service Robots

A Pragmatic Approach to the Integration and Adoption of UX in Robotics Companies

Nielsen, Sara

DOI (link to publication from Publisher):
10.54337/aau763801840

Publication date:
2024

Document Version
Publisher's PDF, also known as Version of record

USER EXPERIENCE OF SOCIAL SERVICE ROBOTS

A PRAGMATIC APPROACH TO THE INTEGRATION AND ADOPTION OF UX IN ROBOTICS COMPANIES

BY
SARA NIELSEN

PhD Thesis 2024

AALBORG UNIVERSITY
DENMARK

USER EXPERIENCE OF SOCIAL SERVICE ROBOTS

A PRAGMATIC APPROACH TO THE INTEGRATION AND ADOPTION OF UX IN ROBOTICS COMPANIES

by
Sara Nielsen

AALBORG UNIVERSITY

PhD Thesis 2024

Submitted: November 2024

Main Supervisor: Associate Professor Rodrigo Ordoñez
Department of Electronic Systems
Aalborg University

Co-supervisors: Professor Mikael B. Skov
Department of Computer Science
Aalborg University

Associate Professor Elizabeth Jochum
Department of Communication and Psychology
Aalborg University

Assessment: Associate Professor Astrid Heidemann Lassen (Chair)
Aalborg University, Denmark

Associate Professor Mohammad Obaid
Chalmers University of Technology, Sweden

Professor Minna Susanna Lanz
Tampere University, Finland

PhD Series: Faculty of Engineering and Science, Aalborg University

Department: Department of Electronic Systems

ISSN: 2446-1636
ISBN: 978-87-94563-68-0

Published by:
Aalborg University Open Publishing
Kroghstræde 1-3
DK – 9220 Aalborg Øst
aauopen@aau.dk

ENGLISH SUMMARY

Social service robots are increasingly becoming part of our everyday lives, but robotics companies have faced unexpected difficulties in bringing these robots successfully to market. This dissertation argues that one reason for this is the insufficient integration and adoption of User Experience (UX) in robot development by robotics companies. While the Human-Robot Interaction (HRI) literature has contributed to high-quality design frameworks, these do not adequately balance business needs, technical development, and UX. There is a lack of research that accounts for industry robot designers' requirements for HRI design frameworks, describes the design and development of robots, and addresses the organizational mechanisms influencing UX integration in robot development and adoption within robotics companies. To effectively support multidisciplinary robot design teams' integration and adoption of UX, a better understanding of how robotics companies develop robots is essential.

This dissertation applies a pragmatic research approach to bridge these gaps and addresses the following research questions: *1) What requirements do industry robot designers have for HRI design frameworks?*; *2) how do organizational mechanisms influence UX integration in robot development and adoption in robotics companies?*; and *3) how can robotics companies be supported to integrate and adopt UX?* The dissertation identifies industry robot designers' key requirements for HRI design frameworks, guiding the development of the Robot Design Canvas (RODECA). It introduces digital ethnography as a cost-efficient methodology to enhance traditional competitor analysis, market and application exploration, and integration of UX insights in robot development, while raising contextual sensitivity in robot design teams. Additionally, the dissertation presents the first longitudinal case study and action research on UX integration and adoption in a robotics company. The case study provides rich, contextualized insights into how mechanical and software teams embed UX in robot development. The action research offers a detailed examination of barriers influencing how UX integration and adoption work in a large, well-established robotics company and implements 21 strategies to strengthen UX competencies and cultivate corporate UX.

This dissertation identifies seven organizational mechanism that influence UX integration in robot development and adoption in a robotics company: commitment and support structures, UX as a skill set, coordination of UX, robot development processes, policies for user involvement, understanding authentic users, and contextual integration. My research shows that segmentation is built into the structure of robotics companies, and that UX integration and adoption in this setting require mutual adjustment and tailored initiatives across individual, team, and organizational levels to achieve lasting impact. Treating "robot UX" as "software UX" is a major barrier preventing robotics companies from fully benefiting from and utilizing robots' unique affordances in their design.

DANSK RESUMÉ

Sociale servicerobotter bliver i stigende grad en del af vores hverdag, men robotvirksomheder oplever uforudsete vanskeligheder med at bringe disse robotter ud på markedet. Denne afhandling argumenterer for, at en af årsagerne til dette er den utilstrækkelige integration og adoption af User Experience (UX) i robotudviklingen hos robotvirksomheder. Selvom forskningsfeltet Human-Robot Interaction (HRI) har bidraget med værdifulde design frameworks, balancerer disse ikke tiltrækkeligt forretningsbehov, teknisk udvikling og UX. Der mangler forskning, der tager højde for industrirobotdesigneres krav til HRI design frameworks, beskriver design og udvikling af robotter og addresserer de organisatoriske mekanismer, der påviker UX-integration i robotudvikling og adoption i robotvirksomheder. For effektivt at støtte integration og adoption af UX i multidisciplinære robotdesignteams, er en dybdegående forståelse for, hvordan robotvirksomheder udvikler robotter, essentiel.

Denne afhandling anvender en pragmatisk forskningstilgang for at adresserer disse mangler samt følgende forskningsspørgsmål: 1) *Hvilke krav har industrirobotdesignere til HRI design frameworks?*, 2) *hvordan pårvirker organisatoriske mekanismer UX-integration i robotudvikling og adoption i robotvirksomheder?*, og 3) *hvordan kan robotvirksomheder støttes i at integrere og adoptere UX?* Afhandlingnen identificerer nøglekrav til HRI design frameworks fra industrirobotdesignere, hvilket fører til udviklingen af et Robot Design Canvas (RODECA). Den introducerer digial etnografi som en omkostningseffektiv metodik til at understøtte konkurrentanalyse, udforskning af markeds- og applikationsmuligheder samt integration af UX-indsigter i robotudvikling, samtidig med at den øger kontekstuel følsomhed i robotdesignteams. Desuden præsenterer afhandlingen det første langitudinelle casestudie og aktionsforskning om UX-integration og adoption i en robotvirksomhed. Casestudiet giver rige, kontekstualiserede indsigter i, hvordan to tekniske teams integrerer UX i robotudvikling. Aktionsforskningen tilbyder en detaljeret undersøgelse af barrierer, der påvirker, hvordan UX-integration og adoption fungerer i en stor, veletableret robotvirksomhed, og implementerer 21 strategier til at styrke UX-kompetencer og fremme en virksomhedskultur med fokus på UX.

Denne afhandling identificerer syv organisatoriske mekanismer, der påvirker UX-integration og adoption i en robotvirksomhed: forpligtelses- og støttestrukturer, UX som en færdighed, koordinering af UX, robotudviklingsprocesser, politikker for brugerinddragelse, forståelse for autentiske brugere og kontekstuel integration. Min forskning viser, at segmentering er indbygget i strukturen af robotvirksomheder, og at UX-integration og adoption i denne sammenhæng kræver gensidig tilpasning og skræddersyede initiativer på tværs af individuelle, team og organisatoriske niveauer for at opnå varig effekt. At behandle "robot UX" som "software UX" er en væsentlig barriere, der forhindrer robotvirksomheder i fuldt ud at drage fordel af og udnytte robotters unikke muligheder i deres design.

COLLECTION OF PAPERS

The following four papers are included in this dissertation and can be found in their full length in Appendix B:

Paper I — **Nielsen, S.**, Ordoñez, R., Hansen, K.D., Skov, M.B., and Jochum, E.: RODECA: A Canvas for Designing Robots. 2021. In Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction. Association for Computing Machinery, Boulder, CO, USA, 266–270. DOI: 10.1145/3434074.3447173

Paper II — **Nielsen, S.**, Skov, M.B., Hansen, K.D., and Kaszowska, A.: Using User-Generated YouTube Videos to Understand Unguided Interactions with Robots in Public Places. 2023. In ACM Transaction on Human-Robot Interaction. DOI: 10.1145/3550280

Paper III — **Nielsen, S.**, Skov, M.B., and Bruun, A.: User Experience in Large-Scale Robot Development: A Case Study of Mechanical and Software Teams. 2023. In Human-Computer Interaction INTERACT'23. DOI: 10.1007/978-3-031-42283-6_3

Paper IV — **Nielsen, S.**, Ordoñez, R., Skov, M.B., and Jochum, E.: Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Large Organization Developing Robots. 2023. In Journal of Behaviour & Information Technology. Taylor & Francis Group. DOI: 10.1080/0144929X.2023.2227284

ACKNOWLEDGEMENTS

While writing a dissertation and driving Ph.D. research can sometimes feel lonely, I have never felt alone and for that I have several people to thank in this acknowledgement.

To my former colleague and supervisor, Karl, thank you for trusting a group of Engineering Psychology students to work on the Kugle robot back in 2017. This is what spiked my interest in HRI. Also, thank you, Rasmus and Søren, for helping me formulate the Ph.D. proposal. Without the three of you, I would not haven been given this opportunity.

I sincerely thank my three Ph.D. supervisors. Rodrigo, for ensuring that I had the resources and means to do research. Mikael, for the opportunity to learn from you and for helping me keep my cool when things became messy. Elizabeth, for your continuous support since I first dipped my toes in HRI; your enthusiasm is not only admirable but also transmittable. You have all inspired me to become a better researcher and have unquestionably raised the quality of my work, for which I am truly grateful.

This research would not have been as exciting without the robotics companies I have had the joy of collaborating with. Thank you for welcoming me with open arms.

To my closest collaborators, thank you. Claudio, Stefano, and the Design Thinking for Business research group. I enjoyed my time in Milan and I hope we meet again. Anders Bruun, for your insights and for presenting our work while I was on maternity leave. I still owe you a beer. Aleksandra, for the countless conversations, sparring, support, always having your door open, and for being an incredible colleague and my Ph.D. fairy godmother. I do not know how to repay you. Dimitris, for spending considerable time advising me in the final phase, reading my drafts, and providing on-point practical feedback and support. The thesis would not have turned out this well without your help. Louise, for being an outstanding boss, giving me time and space to focus on finishing the dissertation. Your generosity makes me speechless! Thank you to my colleagues at AIS and HCC, as well as to Peter, Martin, Steffen, Andreas, and Aysegül from my Ph.D. network.

My deepest gratitude goes to the love of my life, Sindre, for your unconditional love and support. Thank you for always being there, listening, and guiding me through the ups and downs. When work becomes overwhelming, you pick up the pieces and ensure that I can do my best. I know that this year has been challenging, as you have been taking care of our baby girl and managing everything that comes with being house owners and a family. My love and admiration for you are endless, and I will do my best to make it up to you! Olivia, my baby, watching you grow gives me so much joy, and you have shown me that I can accomplish much more with limited sleep than I could ever imagine. For you, I will do anything!

CONTENTS

LIST OF FIGURES

1 INTRODUCTION

This dissertation investigates how to bridge industry needs and requirements with User Experience (UX) towards the successful development of social service robots. Specifically, it answers what requirements industry robot designers have for design frameworks; how UX can be integrated and adopted by industry robot designers involved in the development of social service robots; and which mechanisms influence the integration and adoption of UX. In this introduction, I outline in detail the importance of integrating and adopting UX in robot development and identify research gaps within the Human-Robot Interaction (HRI) literature that motivate my research questions. The introduction additionally details how UX is considered in this dissertation and describes the class of robots in focus (social service robots). Afterwards, the introduction provides an overview of the role of design in HRI and posits that UX in robotics should be a collaborative endeavor. Lastly, this introduction presents the research questions and outlines the dissertation.

Deploying social service robots into real-world contexts has gained considerable attention both in academic circles and industry. However, several robotics companies are unable to sustain their businesses, as the robots fail to generate the expected value for the business, customers, and authentic users (Tulli, Ambrossio, Najjar, & Lera, 2019; Bartneck, 2020). Five reasons have been identified as to why many robotics companies fail in markets outside industrial manufacturing (Dietrich, Dance, & Tolson, 2021):

Lack of business sense is enforced by the lack of established business models, pricing strategies, and other best practices. This failure is propelled by many founders of robotics companies being technical experts as opposed to business leaders, which manifests in how some robotics companies fail to strategically manage their funds during product development and after the robot launch (Dietrich et al., 2021). Insufficient business sense is a particular problem for spin-off and startup companies born out of universities, as academic researchers are rarely prepared to enter into the private sector (Tulli et al., 2019).

Poor market fit and timing is caused by issues of combining technology readiness levels and ability to solve specific problems for authentic users. Robotics companies that suffer from poor market fit and timing are either too early or too late to the market, or face challenges with robots that are too expensive to bring to market in a reasonable time frame (Dietrich et al., 2021). Poor market fit and timing can cause robotics companies to shut down because they offer over-priced, over-engineered, and under-delivered solutions that do not solve an actual problem, or the robot becomes more expensive than the problem itself. Circumventing this issue requires dedicated attention to the discovery of what the market actually needs, and then assessing whether and how this can be achieved by a robot.

Misalignment between investors and partners is caused by lack of shared vision, as well as poor and inconsistent communication. Choosing strategic investors and partners is crucial in robotics, and robotics companies should strive to find partners who support experimental prototyping during development and provide opportunities for understanding the users through real-world exploration and testing, which will also ensure a better integration of the robot into the target environment (Dietrich et al., 2021).

Bad UX and integration with existing workflows is detrimental to the success of robots. Decisions to invest in robots are influenced by factors related to UX in that most robots require time for users to learn how to set up, operate, service, and maintain the robot (Dietrich et al., 2021). Delivering good UX requires that robotics companies identify and address concrete real-world problems and focus precisely on solving those problems by developing only the required features and providing easy-to-use interfaces.

Lack of understanding authentic users leads robotics companies to focus on the wrong problems. This technology-first approach, disconnected from the real-world and authentic users, results in robots designed with an abundance of features and capabilities (Dietrich et al., 2021). Feature creep in robotics is associated with increased cognitive load, usability risks, technical debt, development costs, time, and training efforts (Dietrich et al., 2021).

Interestingly, technology issues are not listed as a reason why robotics companies fail. Instead, technology issues–when considered in terms of why robotics companies fail–arise due to a mismatch between the technology readiness level and the robot's ability to meet authentic users' needs (Dietrich et al., 2021). Striking this balance is crucial as technology issues prevent long-term investigations of and engagement between people and robots deployed in social contexts (Liu, Tetteroo, & Markopoulos, 2023). When robots are designed with too many features and capabilities, the technology might not be able to support this in a cost-effective, convincing, and acceptable way (Mahdi, Akgun, Saleh, & Dautenhahn, 2022). This can be avoided if UX is properly embedded in the robot design process and allowed to influence design decisions, thereby directing development efforts towards relevant components of the robot. Contrarily, it may be difficult to design robots based on UX alone. For example, if the gap between what is shown to authentic users and what is technical feasible is too big, it could result in disappointment with the robot's capabilities (Liu et al., 2023).

Incorporating UX into robot development is crucial for the successful commercialization of robots (Lindblom, Alenljung, & Billing, 2020; Dietrich et al., 2021). While UX alone does not guarantee commercial success, as it is intertwined with technology, market fit, and timing, it can enable robot designers to address real problems rather than solving vague or hypothetical problems. Poor UX can result in reluctance towards using robots, erroneous handling, and a bad reputation for robots (Alenljung, Lindblom, Andreasson, & Ziemke, 2017). A strong focus on UX is therefore essential to ensure robots are user-friendly and well-received in the market. This is especially important for interactive robots deployed in social contexts as service tools. Such robots are expected to operate unsupervised in human populated environments, where people who are not the target users make up most of the robots' encounters. There is a high probability that these people have substantially different expectations and requirements compared to the primary user and thus interact with the robot in unpredictable ways. It is therefore not enough just to design robots with only the primary user in mind– despite this being a challenge in itself.

In order to address this challenge, industry robot designers need research-based guidance on how to choose and apply relevant and correct UX techniques and methods, and such techniques and methods should have practical applicability (Lindblom & Andreasson, 2016). As few service robots deployed in social contexts so far have progressed from research test-beds to commercial success (Sandoval, Brown, & Velonaki, 2018), it is surprising that the issue of balancing business needs, technical development, and UX has received little attention in the HRI literature. Furthermore, while robot design frameworks in HRI literature are manifold and, in rare cases, evaluated in terms of utility by robot designers (Axelsson, Oliceira, Racca, & Kyrki, 2021; Wallström & Lindblom, 2020), there has not been much focus on identifying industry robot designers' requirements for HRI design frameworks that integrate with their development practices. Similarly, information about how robots are designed is fragmented, and there does not exist a consistent body of research describing the design process of robots (Sandoval et al., 2018). One notable exception is the work of Alves-Oliveíra et al. (2022), who found that robot design is either iterative, linear, or based on data points (i.e., the design is based chiefly on prior knowledge or accumulated observations particularly drawing on HRI research). Alves-Oliveíra et al. (2022) additionally discovered that the degree of user involvement in robot design varied from authentic users being minimally or not at all involved in the design process, involved in the actual design process, considered as a reference point (i.e., users' needs guide the development, but users are not directly involved in the process), or treated as theoretical constructs based on robot designers' assumptions. Although this work provides insights into how robots are developed from the perspective of the designer, it does not address the underlying mechanisms that influence the design process. Thus, we have yet to uncover how organizational mechanisms impact UX integration and adoption in robot design. Obtaining such knowledge is crucial if we intend to support the robotics industry in adopting and integrating UX, and is key to filling this gap in knowledge.

This dissertation adopts a pragmatic research approach to uncover requirements that industry robot designers[1] have for HRI design frameworks and how organizational mechanisms influence UX integration and adoption in robot design taking place within robotics com-

[1]**Industry robot designer(s)** (and occasionally 'practitioners') is used as an umbrella term to refer to any one involved in the design and development of robots in the industry.

panies[2]. Based on the empirical findings, this dissertation provides applicable strategies on how to integrate UX in robot development and adopt UX within robotics companies. The strategies are meant for robotics companies that see the value of UX–regardless of what that value might be–but struggle to integrate UX in robot development and adopt UX across the organization. The dissertation specifically focuses on robotics companies with in-house design and development of their own social service robots, which includes the design of the robot's communication and screen-based interaction capabilities.

1.1 User Experience (UX)

It is not enough to design products with good usability: users expect that as the bare minimum from the products they encounter and interact with (Hassenzahl, 2010). Users increasingly expect that products are meticulously designed and facilitate certain experiences. UX has become a competitive advantage allowing companies to build innovative and engaging experiences incorporated in their products, thereby differentiating themselves in the market. Evidencing the commercial value of UX embedded into product development and organizational culture, Sheppard et al. (2018) found that companies[3] with strong design capabilities regarding UX, human-centered design, and design management outperformed industry-benchmark growth by two to one. Successful companies 1) measured and managed design performance with the same rigor as revenues and costs; 2) broke down internal walls between physical, digital, and service design; 3) made human-centric design everyone's responsibility; and 4) de-risked development by continually listening, testing, and iterating with end-users (Sheppard et al., 2018).

Among varied definitions, ISO 9241-210:2019 (2019, p. 4) defines **UX** as a "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service". Extending this, the ISO notes that UX "include[s] the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use" (9241-210:2019, 2019, p. 4). It likewise recognizes that brand image, presentation, functionality, system performance, and interactive behavior of a product[4] and a person's prior experiences, attitudes, skills, abilities, personality, and context of use impact UX (9241-210:2019, 2019). Another widely accepted definition of UX has been suggested by Hassenzahl and Tractinsky (2006):

> "UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g.

[2] **Robotics companies** refers to companies which only develop robots as well as robot developing organizations, where robots are only one part of the company's product portfolio.

[3] The McKinsey report authored by Sheppard et al. (2018) is based on data from 300 companies across product- and service-based sectors, which were followed over a five year period.

[4] For simplicity, I write *product*, but this applies equally to *services* and *systems*.

> complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)" (Hassenzahl & Tractinsky, 2006, p. 95).

According to Kuusinen (2015), Väänänen et al. (2008), Rajanen et al. (2017), and Kashfi et al. (2017), practitioners often equate UX with pragmatic aspects such as functionality and usability, without considering the hedonic and emotional aspects. Reducing UX to matters of functionality and usability raises the risk of designing well-functioning products that nobody wants, as the product does not solve an actual problem in a meaningful way. Failing to form an appropriate and complete understanding of authentic user needs is a major cause for systems failure (9241-210:2019, 2019), which can be linked to two of the reasons why robots fail in the market, namely; poor UX and integration with existing workflows and lack of understanding authentic users (Dietrich et al., 2021).

UX is realized through **human-centered design** (HCD)[5], which is defined as an approach:

> "[...] to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques" (9241-210:2019, 2019, p. 2).

Adopting a HCD approach improves UX and increases commercial success by generating substantial economic and social benefits for users, employers, and suppliers (9241-210:2019, 2019). HCD similarly increases the likelihood that multi-disciplinary teams successfully complete their projects on time and within the budget while effectively reducing risks of failing to meet stakeholder and authentic user requirements (9241-210:2019, 2019).

I additionally draw on **Design Thinking**, which is one of the most popularized HCD approaches to tackling wicked problems across industries (Brown, 2019), and is deeply intertwined with UX in industry practices (Gothelf & Seiden, 2016; Carlgren, Rauth, & Elmquist, 2016). Design Thinking considers business needs, technology development, and UX throughout: "[...] *inspiration*, the problem or opportunity that motivates the search for solutions; *ideation*, the process of generating, developing, and testing ideas; and *implementation*, the path that leads from the project room to the market" (Brown, 2019, p. 22) and is defined as:

> "[...] a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (Brown, 2008, p. 86).

[5]The ISO 9241-210:2019 highlights *human* instead of *user* to emphasize that all stakeholders expected to be impacted directly or indirectly by a product should be considered; not just the primary end-user (9241-210:2019, 2019). Even so, human-centered design is often used synonymously with user-centered design.

Design Thinking has proved useful in a variety of situations, including product development and organizational management (Magistretti et al., 2022; Rosenberg, Chauvet, & Kleinman, 2015), and recently found way into HRI (McGinn et al., 2020). More importantly, it has a track record as a systemic approach to innovation that is capable of generating higher sales, increasing profit margins, and reducing costs, while empowering businesses across industries to develop products and experiences that fulfill authentic needs (Brown, 2019).

Designing products with good UX can be accomplished through various HCD approaches and frameworks, and requires that UX is embedded and prioritized at all stages of product development. Successful companies recognize the importance of allowing UX to extend beyond product development to influence strategies, culture, and decision-making processes (Sheppard et al., 2018). This dissertation is distinctively interested in both product development and organizational mechanisms that influence how robotics companies integrate UX into development and adopt UX within the organization. As aspects are not included in definitions of UX, I adopt Levy's (2021) explanation of **UX strategy**:

> "[...] most frequently used to mean strategically executing UX at a particular organization or business unit: how the UX department should be run, how to assess and grow your team's capabilities, how to broaden your UX team's reach and influence, and how to prioritize UX projects that can have the most return on investment" (Levy, 2021, p. 5).

This definition aligns with a pragmatic process focus and brings together business strategy, value innovation, validated user research, and UX (Levy, 2021). UX strategy begins in the discovery phase and is key to avoiding surprises, because user research influences product development (Levy, 2021). With her notion of UX strategy, Levy (2021) widens the scope of UX by placing it within an organizational setting, thereby emphasizing the importance of **design management**, which can be defined as:

> "[...] the ongoing management–and leadership–of design organizations, design processes, and designed outcomes (which include products, services, communications, environments, and interactions)" (R. Cooper, Junginger, & Lockwood, 2009, p. 50).

Design management deals with "the (strategic) selection and mobilization of sets of activities, practices, capabilities, and (organizational) resources necessary for [a] product to be developed" (Carneiro, da Rocha, Rangel, & Alves, 2021, p. 198). **UX strategy** covers both design management perspectives and the specific UX activities needed at the product level (such as conducting user studies), as they are seen as means to strategically execute UX within an organization or business unit. Although attending to the organizational side of UX integration and adoption is crucial for developing applicable HRI design frameworks and for robotics companies to design robots with excellent UX, this has hitherto not received much attention in HRI research. This dissertation presents empirical findings into these topics.

1.2 Social Service Robots

Incorporating UX in robot development is vital, given that the second wave of successful commercialization of robots–following the ongoing automatisation of industrial production–is expected to come from introducing service robots into dynamic and open environments (Bartneck et al., 2020). ISO 8373:2021 (2021) defines **service robots** as:

> "[robots] in personal use or professional use that performs useful tasks for humans or equipment" (8373:2021, 2021, p. 2).

In essence, service robots deliver services and support to people in a variety of situations, e.g., facility management and hospitality. Thrun (2004) similarly differentiates between **professional** and **personal** service robots. The former refers to robots that assist people in achieving professional goals, e.g., assisting cleaning personnel, whereas the latter pertains to robots that assist or entertain people in domestic settings or during recreational activities (Thrun, 2004). Social service robots which operate in facility management and hospitality, as professional service tools or as personal service agents, are of particular interest to this dissertation; they are designed to be deployed in public spaces, and are operated on a regular basis either by operators (e.g., cleaning personnel and their supervisors) to achieve professional service goals, or by InCoPs during more spontaneous and short-term encounters.

As this dissertation focuses on social service robots meant for professional and personal use in human-populated environments, I draw from research on social robots as this subfield has produced several publications regarding UX. Breazeal (2003) defines **social robots** as:

> "those that people apply a social model to in order to interact with and to understand" (Breazeal, 2003, p. 168).

The social model that people form of robots relies heavily on the extent to which a person anthropomorphizes (ascribes human-like attributes to objects) the robot. Breazeal (2003) differentiates between several types of social robots. **Socially evocative** robots are designed to encourage anthropomorphism to facilitate interaction but lack the ability to reciprocate. Robots with a **social interface** emulate human-like social cues and communication modalities at the interface level in order to facilitate more natural and familiar interaction, whereas **socially receptive** robots learn from the interaction, primarily through human demonstration, while utilizing social cues and communication modalities but only after the fact. Lastly, **sociable** robots proactively engage with people in a social manner. By taking advantage of the aforementioned characteristics, sociable robots learn from the environment and interactions with people to continuously improve (Breazeal, 2003). Fong, Nourbakhsh, and Dautenhahn (2003) contribute three additional classifications: **Socially situated** robots that are surrounded by social environments where they perceive and react to other social agents; **socially embedded** robots that are embedded in and structurally coupled to the social context and interact with people and other agents complying with human norms; and **socially intelligent** robots that mimic close to human-like social intelligence (Fong et al., 2003). Rather than seeing these categories as mutually exclusive, Breazeal (2003) treats them as prerequisites or steps for continuously improving and furthering the robot's abilities. This could be interpreted as if Breazeal (2003) positions **sociable** as the end goal of social robot development and that, in order for a robot to become sociable, it must utilize social cues and communication modalities that people use, as well as exhibit proactive behavior. However, not all robots make explicit use of human-like features, social cues, or communication modalities in order to successfully communicate and express intentionality, nor do they have to (Hoffman & Ju, 2014). Bartneck and Forlizzi (2004) offer an alternative definition of **social robot**:

> "[...] is an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact" (Bartneck & Forlizzi, 2004, p. 592).

This definition presumes physical embodiment and emphasizes that social robots should attune to those behavioral norms that are expected in a given interaction and context. In comparison, this definition does not appear to require that the robot possess human-like features, social cues, or communication modalities, as emphasized by Breazeal (2003), for it to be considered a social robot. One argument to make is thus that, when robots possess safety features, it usually implies that they are not restricted to enclosures but rather operate with and among people, and when that happens, people are more prone to ascribing the robot social agency (to varying degrees depending on the robot's technical capabilities as illustrated by Breazeal's (2003) taxonomy). Embedding social features into robots is, and will continue to be, a concern of robot designers and researchers, as such features improve the interaction experience and promote long-term engagement and use (Mahdi et al., 2022). Based on these definitions and classifications, service robots can therefore also be considered social robots as they communicate, coordinate, interact, and share physical spaces with people. The dissertation uses **social service robots** yet conforms to the terminology (e.g., 'service robot' and 'social robot') chosen by cited authors throughout the dissertation.

In summary, this dissertation considers multi- and single-purpose embodied robots that operate with and among people as professional service tools for operators (e.g., cleaning personnel and supervisors) and/or as personal service agents for the general public in a variety of contexts (e.g., shopping malls and airports). Consequently, the social service robots considered in this dissertation[6] interact and communicate with a broad range of people including operators, service technicians, and the public represented by InCoPs. Furthermore, this dissertation focuses on robotics companies developing their own robots, rather than retrofitting and customizing the software of existing commercial robots, such as Peppers and NAOs. Thus, the dissertation concentrates on the design and development of the robot itself, alongside consideration of the ways people interact and communicate with the robot.

1.3 The Role of UX in Human-Robot Interaction

Design has become an important subfield within HRI and addresses the development of new robot morphologies, appearances, behaviors, embodiments, and interaction possibilities. The importance of such discussions was underscored by the International Conference on Human Robot Interaction with the development of the first Design Track in 2015, and emphasized in the introduction to the special issue on the role of designing affective embodied interactions in 2023 (Paterson, Hoffman, & Zheng, 2023). The initial design tracks have however been criticized, as contributions "present[ed] the development and evaluation of a standalone and unique robotic solution" (Lupetti, Zaga, & Cila, 2021, p. 391) where design was seen as a means for investigation, rather than its own discipline. According to Lupetti et al. (2021) it was not until 2017 that the design process itself came into focus in HRI. Despite the growing interest in design, most HRI studies focus on evaluating usability or acceptability aspects. Perhaps this is because robots like NAO, Pepper, Keepon, Paro, and Baxter have dominated the field of social robotics and HRI for several years due to their affordability, robustness, and ease of programming that enable researchers to investigate various aspects of HRI (Bartneck et al., 2020). While researchers emphasize the uniqueness of physical embodiment that sets robots apart from other computer technologies (Bartneck et al., 2020; Thrun, 2004; Paterson et al., 2023), utilizing these popular robots does not allow for much exploration of embodiment, as the physical design of the robots are already defined. However, this has changed dramatically with the introduction of 3D printers and AI powered software, which enable HRI researchers to design and fabricate entirely new robots. Consequently, the subfield of robot design has rapidly expanded, with many more researchers calling themselves *robot designer*, although they might not have a background or formal training in design.

In spite of this, robots that operate in human populated environments continue to fail in the market (Bartneck, 2020; Dietrich et al., 2021), and we have not seen an increase of commercial success of robots operating outside production lines. This is partially the result of not considering UX holistically and beyond the product level by accounting for how robots impact and integrate with existing workflows (Dietrich et al., 2021). One such case is the famous hospital study carried out by Mutlu and Forlizzi (2008), who found that although the robot

[6] The robotics companies and the robots that I have worked with and studied are presented in Section 3.2.2.

(a delivery robot) was well received by certain hospital units as it reduced their workload, it also increased the workload of others, resulting in people physically and verbally abusing the robot. While this paper was published in 2008, subsequent studies reported similar issues in 2018: Kadir et al. (2018) found that companies which had invested in collaborative robots either sold their robots about a year after having purchased them due to underutilization (which could not justify the investments), or stored the robots in the basement to collect dust. This negative trend continues to spread. The security robot, KnightScope K5, was recently retired (February, 2024) from duty in New York City's subway system, as people consistently ignored and ridiculed the robot, and the robot required unanticipated supervision from policemen (Rubinstein & Meko, 2024).

That design has taken root in HRI seems to pave way for an increasing interest in supporting robot designers to design for good UX (Lindblom & Andreasson, 2016). This has manifested in research efforts towards proposing HRI design frameworks and appropriating design practices from fields like Human-Computer Interaction (HCI). Even so, how UX is considered in and operationalized by existing HRI design frameworks varies greatly, and despite promoting more holistic approaches that account for user's internal states, the design of the robot, and the context of the interaction, these design frameworks focus chiefly on the product level of UX. Against this backdrop, this dissertation is concerned with the broader picture of UX integration and adoption that extends beyond the product level to encompass aspects of UX strategy in robot design and robotics companies, as this has not been sufficiently addressed in HRI literature and is key to supporting robotics companies to integrate and adopt UX.

Although robot designers call for design frameworks that integrate UX as means to increase the likelihood of designing commercially viable robots (Tonkin et al., 2018), current legislation may hinder the design of intuitive and seamless interaction with social service robots. There are several safety requirements and protective measures outlined in ISO 13482:2014 (2014) and the European Machinery Directive (2006) regarding the physical (shape, materials, external parts), ergonomic (minimize or reduce uncomfortable postures causing discomfort experienced by the targeted users), sound (design low-noise machines using sound-damping/absorbing materials and active noise cancellation), and behavioral (preserving the highest level of stability in all cases) design of personal care robots (13482:2014, 2014) and machines in general (Parliament & the Council of the European Union, 2006) which must be complied with[7]. Also, while there is a push towards designing explicitly for user needs, doing so may be in direct violation with the General Data Protection Regulation (2018) concerning, e.g., the use of facial recognition software and cases where users may want the robot to synchronize information from MS Outlook or Teams (Pimminger et al., 2024). Even though

[7] At the time of writing, the ISO for service robots has not been released, which is why the ISO 13482:2014 is consolidated as personal care robots share more resembles with service robots than industrial and collaborative robots, which have their own safety standards.

compliance is essential to providing robust, reliable, and safe interactions, these standards do not necessarily guarantee good UX. There is, for example, no mention of how robot designers can design for coherent and positive UX regarding the robot's physical, ergonomic, sound, and behavioral design. Rather, the standards offer the minimal technical requirements that robot designers must ensure their robots comply with.

While researchers emphasize the importance of evaluating the UX of robots, systematic incorporation of UX from a process perspective has received little attention. This is problematic because positive user experience is not coincidental, but has to be systematically and purposefully designed for (Alenljung et al., 2017). Despite this, UX is often treated haphazardly and superficially, limited to evaluation activities, or even omitted in favor of the technical system development (Alenljung et al., 2017). For instance, robot developers tend to "cook up" methods for evaluating UX-related aspects, which can lead to unreliable insights and drive questionable design decisions (Bartneck, Kulić, Croft, & Zoghbi, 2009). Developers' biases and preferences can also influence design decisions, especially when users are not sufficiently considered at the inception of robotics projects (Sandoval et al., 2018). This is likely the result of traditional robot development being inherently technology-centered and guided by technical requirements for executing well-defined tasks, with the risk of overlooking important aspects of design (McGinn et al., 2020). A technocentric view may enable robot designers to develop robots that fulfill technical specifications, but this may not be sufficient for successful interaction nor integration within social contexts (Šabanović, 2010). Robot designers would do well to favor approaches that consider pragmatic and utilitarian aspects, as well as emotional and hedonic aspects (de Graaf & Allouch, 2013). This calls for collaboration and cross-pollination, as well as willingness to approach robot design from a place of interdisciplinary curiosity and mutual respect.

1.4 UX in Robotics as a Collaborative Endeavor

The field of HRI is recognized as an interdisciplinary field bringing together engineers, roboticists, social scientists, psychologists, and, more recently, designers. However, in industrial contexts, additional competencies (such as software developers, mechanical designers, supply chain managers, test engineers, and marketing) are required to successfully bring robots to market. Axelsson et al. (2021) highlight that coordination and collaboration between teams can be a substantial challenge to overcome, and Šabanović et al. (2009) argue that developing robots for social contexts requires collaboration, not segmentation, across disciplines. These authors recognize the challenge of managing the design of robots due to the diversity of domains and expertise required to build systems as complex as robots. My research will show that this segmentation is built into the structure of robotics companies and manifest in how they design robots, making obstacles difficult to overcome. It is not that robot designers do not know that interdisciplinary collaboration is necessary: it is that such collaboration is inherently challenging in industry contexts.

Involving practitioners from robotics companies, whose practices and processes would in someway be affected by changes suggested in this dissertation, is critical when the aim is to both understand and influence the situation (Buchner, Mirnig, Weiss, & Tscheligi, 2012; McKay & Marshall, 2001; Stark, 2014; Kidd & Kral, 2005). I therefore sought out contributions from UX practitioners[8] because I expect them to be the main drivers of UX integration and adoption as well as from project managers and team leaders from mechanical, software, and hardware teams, as they coordinate and collaborate with UX practitioners, and consequently influence UX integration and adoption. Such collaboration is at the heart of the pragmatic orientation adopted in this dissertation and is necessary to strengthening knowledge exchange on design issues between the academic field of HRI and the robotics industry, which has to date not been explicitly addressed in HRI (Cila, González González, Jacobs, & Rozendaal, 2024). This dissertation thus contributes to the important conversation of UX in robotics and addresses contemporary issues of opening up the design of robots to practitioners not formally trained in UX, and thereby supports robotics companies in integrating and adopting UX.

1.5 Research Questions

The gaps highlighted in the introduction pertain to issues of balancing business needs, technical development, and UX in robot design and lack of research accounting for industry robot designers' requirements for HRI design frameworks; describing the design and development of robots; and addressing the organizational mechanisms that influence UX integration in robot development and adoption in robotics companies. To address those gaps, research into UX integration and adoption in robotics must consider the organizational context of robot design. This dissertation adopts a pragmatic research approach to bridge these gaps, providing an empirical account of industry robot designers' requirements for HRI design frameworks and the mechanisms that influence UX integration and adoption in robot development. Understanding these requirements and mechanisms may inform strategies to support UX integration and adoption in robotics companies. This section presents the research questions, briefly addresses their handling, and outlines the dissertation.

The following research questions are explicitly addressed in this dissertation:

1. What requirements do industry robot designers have for HRI design frameworks?

[8]**UX practitioner** refers to industry practitioners who plan and execute UX, which for example includes UX specialists and product managers. To distinguish practitioners who are experienced in UX from novices, I use **UX specialist**–and in some cases **UX designer** and **UX consultant**–to refer to the former and **novice UX practitioner** to refer to the latter. In a few cases, **UX lead** is used to refer to the main person(s) in charge of UX.

2. How do organizational mechanisms influence UX integration in robot development and adoption in robotics companies?
3. How can robotics companies be supported to integrate and adopt UX?

In this dissertation, **mechanisms** refer to the inner workings of how an organization functions and operates; it covers, for example, decision-making processes, resource allocation, corporate culture, and management. Practitioners may encounter obstacles that hinder mechanisms from running smoothly, and these obstacles are referred to as **barriers**. To overcome barriers, practitioners can deploy **strategies** which represent actions designed to overcome the barrier. The dissertation additionally differentiates between **integration** and **adoption**. Integration involves incorporating UX practices and processes into the existing robot development workflow, whereas adoption involves efforts towards gaining acceptance of these practices and processes by practitioners themselves, such that they will adopt them.

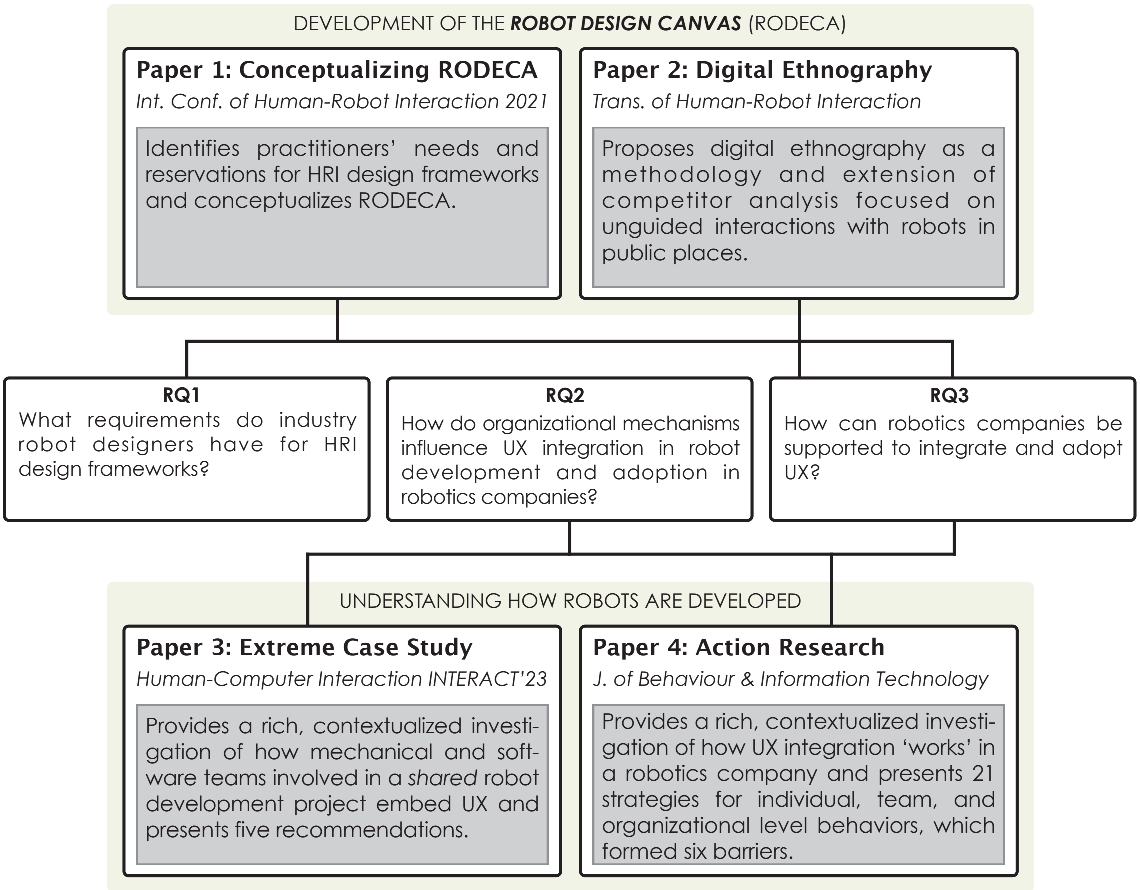

Figure 1.1: Overview of paper contributions and their relation to the research questions.

This dissertation presents empirical findings, which uncover needs and reservations practitioners have regarding HRI design frameworks, how they currently work with UX and how organizational mechanisms impact this, and ways in which robotics companies can be supported in integrating and adopting UX. Implicated by its pragmatic orientation, this dissertation presents two research streams, which are visualized in Figure 1.1 and explained in-depth in Section 3.2.1, which connects the four papers to the three research questions.

The outline of this dissertation is as follows: **Chapter 2** presents related work that was instrumental to formulating the research questions. The chapter introduces HRI design frameworks, UX integration within agile software development environments, and design management perspectives. **Chapter 3** presents the research design. **Chapter 4** presents the four paper contributions, and **Chapter 5** discusses the empirical findings against the identified gaps, which informed the research questions. Chapter 5 ends with a discussion of the dissertation's limitations. Lastly, **Chapter 6** concludes the dissertation by answering the research questions and suggesting avenues for future work.

2 RELATED WORK

This dissertation identifies industry robot designers' requirements for HRI design frameworks and investigates UX integration in robot development and adoption within robotics companies, rather than focusing on the design of specific robots. This chapter first introduces examples of existing HRI design frameworks that illustrate different approaches to robot design and contributed to the conceptualization of the first version of the **Robot Design Canvas** (RODECA). Second, research highlighting challenges researchers and practitioners have faced regarding UX integration and adoption in software development is summarized. Third, design management–when UX strategy meets the organization–is addressed, which is crucial to consider, as UX integration and adoption will require organizational shifts.

2.1 Human-Robot Interaction Design Frameworks

The HRI community has developed numerous evaluation methods in the form of questionnaires, such as the Negative Attitudes toward Robots Scale (Nomura, Suzuki, Kanda, & Kato, 2006), the Persuasive Robots Acceptance Model (Ghazali, Ham, Barakova, & Markopoulos, 2020), the Robotic Social Attributes Scale (Carpinella, Wyman, Perez, & Stroessner, 2017), or the Godspeed questionnaire, which assess people's perception of a robot's anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety (Bartneck et al., 2009). These evaluation methods are frequently used after a robot design has been chosen, and thus offer little guidance on the process of designing the robots. Consequently, researchers can modify the robot's behavioral models, but the physical characteristics will remain largely unchanged. This section presents examples of universal design practices applied in HRI, followed by HRI design frameworks that concentrate on robots' behavioral design. Lastly, the section provides examples of HRI design frameworks that combine universal design practices with attention towards robots' behavioral design and incorporate UX.

2.1.1 Universal design practices applied in HRI

Various universal design practices have been applied and adapted to robot design. Universal design practices refer to practices that transcend disciplines and research fields proving useful in both digital and physical product design. The section provides a general overview of how prototypes support iterative design activities, context exploration, and Design Thinking; how usability evaluations can provide valuable insights during the design of robots; and how Participatory Design has provided authentic users with decision making power.

Exploratory prototyping

Prototypes, defined as a "representation of all or part of an interactive systems, that, although limited in some way, can be used for analysis, design and evaluation" (9241-210:2019, 2019, p. 3), play a fundamental role in HCD approaches as it enable designers to communicate and explore several design ideas in parallel and through iteration, converge a design towards what authentic users actually desire. Building and evaluating prototypes are ways to operationalize UX and materialize design ideas. Using **exploratory prototyping** underscores the importance of prototyping in early phases of robot design processes as doing so can help teams uncover tacit user needs and behaviors and issues with the current design as well as mature and concertize design ideas thereby reducing uncertainty and development risks. **Exploratory prototyping** in robotics faces unique challenges compared to prototyping software products. While software prototypes can be rapidly and cheaply modified and updated, robot prototypes require consideration of materials, electronics, physical constraints, safety requirements, and manufacturing feasibility. These constraints make it harder to implement exploratory prototyping methodologies commonly used in software development and necessitate adaptation of such methods to account for the physical nature of robots. Even so, prototyping is a widely adopted practice in HRI, thus this section presents examples of how prototyping can raise robot designers' contextual sensitivity, engage authentic users in the design of the robot, and provide evidence to make informed decisions regarding the robot's design.

We develop products thinking that they will be used in a certain way, and robots are no different. Šabanović (2010) and Šabanović et al. (2014) argue that robot designers' assumptions about how people will use and interact with a robot once deployed rarely hold true. A good example of this is the hospital study conducted by Mutlu and Forlizzi (2008), who found that, while the autonomous delivery robot alleviated the workload of some hospital staff units, it caused frustration and imposed additional workload on others. To overcome this, Šabanović et al. (2014) posit that building prototypes to be evaluated early and often in-situ, as well as comparing design alternatives to understand how specific attributes of the robot perform in the actual context, will help robot designers gain contextual knowledge needed to design robots that generate value for authentic users. An essential first step of the robot design process should be context exploration, which attends to peoples' routines and behaviors in the chosen environment, in combination with initial design of a technological solution (Šabanović et al., 2014). Second, a comparison of a physical embodied prototype and a virtual prototype should be made to establish whether there is empirical merit for pursuing development of an embodied robot, as opposed to a simpler desktop solution. Third, robot designers should examine the effects of the robot's social interactivity relevant to the context and authentic users. Similarly, Carrillo et al. (2018) propose a two-phase in situ design process for adapting a general-purpose social robot (in this case, NAO) for paediatric rehabilitation. Phase one is an exploratory phase that focuses on eliciting requirements through two key activities: regular and frequent stakeholder engagement and rapid prototyping of roles and capabilities the robot should possess. Phase two focuses on iterative development and in situ evaluation of the first prototype implementation. Like Šabanović et al. (2014), Carrillo et al. (2018) emphasize the importance of designing for and in the actual context and involving authentic users, e.g., by exposing them to the technology, throughout the design process. This, they argue, "promotes transparency in the design process and a sense of ownership of the deployed system" (Carrillo et al., 2018, p. 27). Therapists, for example, were actively involved in designing the robot's capabilities by demonstrating and physically manipulating the robot into relevant positions, which they later programmed into exercises. Carrillo et al. (2018) recognize that their proposed design process might not be appropriate for technical innovation within other areas, but they do not offer a reason as to why.

Exploratory prototyping of robots has also been done by robot design teams adopting Design Thinking. McGinn et al. (2020) developed Personas based on insights gained from the inspiration phase, which is also referred to as the divergent phase (Brown, 2019). This helped build empathy with users across the design team, and provided insights for benchmarking existing solutions and new design concepts to arrive at a set of key features the robot should possess (McGinn et al., 2020). Alternating between divergence and convergence, McGinn et al. (2020) went through concept development (also called *ideation* (Brown, 2019)), where they built and evaluated several prototypes. The team focused on three distinct types of prototypes: 1) 'Dark Horse' prototypes that seem unlikely to work, are high-risk and high-reward, which contributed novel design ideas; 2) a 'funktional' prototype capable of performing the desired tasks, without caring about the robot's appearance; and 3) a 'Part X' prototype focused on finalizing a part of the design that is settled and not expected to change significantly (McGinn et al., 2020). These prototypes were evaluated through focus group interviews, future-telling to explore feasibility and usability issues associated with the robot use-cases, observations from demonstrating the robot at different events, and based on the Godspeed questionnaire (Bartneck et al., 2009).

Formative usability evaluation

Usability evaluation has been widely adopted within HRI (Moshkina, Endo, & Arkin, 2006; Broadbent, Montgomery Walsh, Martini, Loveys, & Sutherland, 2020; Li et al., 2022), and according to Zhong and Schmiedel (2021) summative usability evaluations are more frequently used in designing social robots. Summative usability evaluations typically assess the frequency of usability problems once a product has been developed. In contrast, Zhong and Schmiedel (2021) used formative usability evaluations, which has been a common practice in agile development for several years (Sy, 2007). Formative usability evaluations help identify issues with the design and possible solutions early in the design and development of a product, thereby enabling teams to make incremental improvements to the design. Accordingly, formative evaluations enable robot designers to compare and contrast their designs throughout an iterative development process (Lindblom & Andreasson, 2016). While authentic users participated in the usability evaluations, it was the project partners who partook in idea generation and co-design workshops. Zhong and Schmiedel (2021) explain that both customers' and users' needs were simultaneously cared for; however, it was the company representatives who prioritized design ideas and approved final design decisions. This is problematic in cases where there is a misalignment between what the customer wants and believes users' need, and what authentic users actually need. Buchner et al. (2012) introduced usability evaluations to their industry partner and supported them through preparation, execution, and analysis of gathered data. Although contextual, methodological, and administrative factors impacted the industry partner's ability and willingness to conduct extensive usability evaluations during robot development, the results obtained from limited testing had a considerable impact on the prototype and the development process, ultimately impressing the management with the value these results contributed to the final product (Buchner et al., 2012).

Participatory Design

To level the playing field and enable users to make design decisions together with designers and other stakeholders, HRI researchers have applied **Participatory Design**. Participatory Design considers authentic users of technology as designers, rather than consumers (H. R. Lee et al., 2017; Frederiks, Octavia, Vandevelde, & Saldien, 2019). It builds on mutual learning and shared ownership, rather than enforcing an expert-informant interaction, and places authentic users at the center of the process (H. R. Lee et al., 2017). This sets Participatory Design apart from UX and other HCD approaches, where users are typically involved during specific phases or activities, design decisions primarily rest on designers' interpretation of user feedback, and designers retain control of the process. Inviting users to the center of the co-design process exposes them to the technology and helps them articulate what they need from a robot, while researchers, designers, and developers acquire a nuanced understanding of needs and problems experienced by authentic users (H. R. Lee et al., 2017). This engagement creates trust between the participants involved in Participatory Design (H. R. Lee et al., 2017). Participatory Design has been used in a variety of HRI cases, ranging from co-designing with children (Mott, Bejarano, & Williams, 2022; Obaid, Baykal, Kırlangıc, Göksun, & Yantaç, 2024; Alves-Oliveira, Arriaga, Paiva, & Hoffman, 2021) to conceiving assistive social robots together with marginalized and vulnerable people, such as older adults diagnosed with depression (H. R. Lee et al., 2017), visually impaired people (Azenkot, Feng, & Cakmak, 2016), and people living with motor impairments (Nanavati et al., 2023).

Participatory Design typically includes three phases when used in HRI studies: initial in-situ interviews and site visits, a series of focus group sessions or co-design sessions, and a presentation phase (A. Rogers Wendy, Kadylak, & Bayles, 2022). However, it is often limited to early phases of robot design and the resulting interactive behaviors of the robot are subsequently hard coded by developers or utilized in Wizard-of-Oz setups, and rarely contribute to developing fully autonomous robots (Winkle, Senft, & Lemaignan, 2021). While not progressing to full implementation, Nanavati et al. (2023) involved two researchers with robot development expertise to assess identified design principles according to technical feasibility, and presented an implementation guide that mapped robot features according to user expressed priority and technical complexity (Nanavati et al., 2023). Progressing to implementation, Winkle et al. (2021) proposed a method where domain experts (e.g., teachers and therapists) contributed directly to the development of a robot's behavior and interaction capabilities by teaching the robot what to do in a given case. This method foregrounded domain experts over authentic users and did not seem applicable to robots that were designed to engage in short, sporadic, and unguided interactions with a high number of infrequent users, which several social service robots are designed for.

These examples demonstrate that universal design practices have been extensively applied and adapted to HRI studies using existing robot platforms or to conceive novel robot concepts and prototypes. Furthermore, they seem to work well at specific points during the design process, especially as upfront design activities–a concept which I revisit in Section 2.2. However, given that these design practices do not originate from HRI, they might not take robot behavior sufficiently into account. Behavioral design is important to consider when dealing with embodied and autonomous robots, as they are capable of influencing social structures and evoke agency (Young et al., 2011; Šabanović, 2010). A robot's behavioral design should therefore be considered a fundamental aspect of any design process dealing with physical, embodied robots. The following section therefore presents HRI design frameworks applied to robots' behavioral design.

2.1.2 Robots' behavioral design

Movement and autonomous abilities of physical embodied robots are what sets them apart from other technologies (Chun & Knight, 2020; Forlizzi, 2007; Thrun, 2004), and it is therefore important that a robot's movement accurately express the robot's purpose, intent, state, mood, personality, attention, responsiveness, intelligence, and capabilities (Hoffman & Ju, 2014). Movement thus plays a crucial role in the robot's ability to interact, coordinate, collaborate, and communicate with people. Corrales-Paredes et al. (2023) discovered that incorporating embodiment in robot design improved UX, and that the robot's personality, appearance, behaviors, and ways of communicating had decisive influence of the user's opinions and ways of interacting with the robot. However, robots' interactive behavior is arguably one of the most complicated aspects of robot design (Tonkin et al., 2018), given that the robot's physical appearance, its behaviors, and what it signals must be complementary (Hoffman & Ju, 2014; Tonkin et al., 2018; Holthaus, Schulz, Lakatos, & Soma, 2023). Extending this, Rossi et al. (2020) emphasize that the design of service robots' idle behavior (when not engaged in specific tasks) is as important as the interactive behavior, as it impacts how people who incidentally encounter the robot will perceive it and respond to it. These people are referred to as **incidentally copresent persons** (InCoPs) (von der Puetten, Sirkin, Abrams, & Platte, 2020; Abrams, Dautzenberg, Jakobowsky, Ladwig, & von der Pütten, 2021). This section presents examples of HRI design frameworks specifically targeting behavioral design of robots.

Hoffman and Ju (2014) propose a movement-centric design approach for new robots. Several techniques, such as 3D animation studies, skeleton prototypes, Wizard-of-Oz, sketching, and video prototyping, are used in the exploratory phases, as they allow design teams to work with the expressive capabilities of the robot without having to consider mechanical feasibility (Hoffman & Ju, 2014). This approach additionally relies on puppeteers and animators to iteratively design the robot's movements. Hoffman and Ju (2014) argue that when robots are designed from behavioral aspects, a humanoid form might not be necessary for the robot to interact and communicate with people. This is an important aspect to consider from an industry perspective, because designing non-anthropomorphic robots based on abstract forms is generally cheaper than designing for a humanoid appearance (Hoffman & Ju, 2014). Another design framework that applies (shadow) puppeteering is the Outside-in Design process proposed by Šabanović et al. (2009). This process suggests alternating between real-world observations, technology design, and evaluation to converge on a design of a robot's nonverbal behavior for situated interaction with people (Šabanović et al., 2009).

Designing robot behavior entails much more than making the robot move from location *A* to *B*. To help robot designers think holistically about robot behavior and how it will be perceived and understood by people interacting with the robot, Holthaus et al. (2023) developed a taxonomy that encourages robot designers to reflect upon and make deliberate design decisions regarding the robot's behavior and its signaling value. This taxonomy includes five attributes: **origin**, **deliberateness**, **reference**, **genuineness**, and **clarity**. Put in context, Holthaus et al. (2023) explain that deictic gestures mimic human behavior of pointing towards something, but the sounds of the robot's motor and moving parts are artificial. Likewise, a pointing gesture is intentionally designed in order to enable wayfinding robots to guide a person to a location, whereas the noise produced while making this action is often consequential. A pointing gesture is also considered referential as it reveals a piece of information, whereas the noise is non-referential yet able to communicate whether the robot is operating normally or malfunctions. As for genuineness, Holthaus et al. (2023) refer to whether a behavior is honest (i.e., the robot pointing to the right location) or deceptive (i.e., intentionally pointing to a wrong location). Lastly, a robot's behavior and its signals might be explicit in one context, but implicit and ambiguous in another (Holthaus et al., 2023). These are important attributes to account for in robots' behavioral design, as they have the potential to enable the robot to communicate more clearly with its users within the context of use.

Offering a technical view, Lohse et al. (2014) recommend the Bonsai framework to address issues of iterative design in robot behavior development. Lohse et al. (2014) highlight that implementing insights from user studies in robot development often requires changes to several interconnected components of the system. Consequently, robot developers need to work across hardware, middleware, and architectural levels in order to implement those insights, which is further complicated when developing fully autonomous robots that respond to environmental changes, rather than being hard coded. The Bonsai framework is based on three concepts: **skills** (e.g., following a person to their chosen location) that comprise of **states** (e.g., detect person, announce detection, set location, and initiate guidance) which comprise of **strategies** (i.e., sensors and actuators) that are particularly useful for solving problem-related tasks, e.g., when something unexpected happens at the interaction level. This breakdown enables developers to make changes in only one place; at skill-level as well as re-use states and strategies for designing new skills.

These four design frameworks make valuable contributions to robots' behavioral design from research-led perspectives; however, it is unclear if these frameworks complement existing design and development practices adopted by robotics companies. Furthermore, authentic users play an inferior role compared to experts and researchers themselves. For example, when applied, Šabanović et al. (2009) choose the problem domain based on personal interests and previous experiences, rather than targeting real-world problems experienced by users. Although the Bonsai framework enables robot developers to incorporate insights from user studies, it does not invite authentic users to be part of the actual design process apart from evaluating the robot's capabilities (Lohse et al., 2014). Bringing together universal design practices and attention towards behavioral design, it is time to look at HRI design frameworks that also incorporate UX.

2.1.3 HRI design frameworks integrating UX

This section introduces HRI design frameworks that unite universal design practices and robots' behavioral design, as well as incorporate UX in the design of robots. As this dissertation investigates how robotics companies can be supported to integrate UX in robot development, the following examples are also relevant because they represent cases where industry practitioners were involved in designing the robot and/or in evaluating the proposed design framework.

Axelsson et al. (2021) developed a framework encompassing a design process and tangible design canvases for Participatory Design of social robots. Using the proposed design canvases enables robot design teams to work alongside authentic users to think through a robot's design covering aspects such as the environment the robot is expected to operate in, form, interaction possibilities, behavior, and ethical considerations (Axelsson et al., 2021). Furthermore, the canvases provide a tangible tool for forming a shared language as well as a platform for sharing and reconciling different viewpoints. This was highlighted as an important contribution of the design canvases by stakeholders involved in two distinct social robot design projects (Axelsson et al., 2021). However, the actual implementation of the canvases in the two case studies were accomplished on two existing robots (Furhat and MiR200). Thus, this design process and complementary canvases have not been applied to develop new commercial robots. Furthermore, there are no indications of how applying the design process and canvases work with other development practices (e.g., agile development or New Product Development) used by industry professionals involved in robot development.

The UX of HRI design methodology, proposed by Tonkin et al. (2018), takes multidisciplinary robot design teams through a step-by-step process for systematically designing the UX of a social robot. This methodology builds on Lean UX[1], agile development, Design Thinking, and incorporates central aspects from HRI research (e.g., the design of robot's interactive behavior and personality). They encourage the entire team–also developers–to join in initial field visits and subsequent design and evaluations of the robot. Seeing initial field visits, i.e., context exploration, as a joint team effort was also emphasized in (Šabanović et al., 2014; Carrillo et al., 2018). Exposing team members to the people they design for increases sensitivity towards users in the development and contributes to forming a shared understanding (Gothelf & Seiden, 2016). Tonkin et al.'s (2018) proposed methodology combines industry practices (e.g., customer journey maps and Lean methodologies such as the build-measure-learn loop and validated learning (Ries, 2017)) and HRI design frameworks (e.g., the USUS framework (Weiss, Bernhaupt, & Tscheligi, 2011)). It involves the design of robots' behavior, personality, and identity principles while encouraging the use of corporate branding and values (e.g., logos, colors, and other visual elements) in the design. To ensure that design ideas are technologically feasible to implement, Tonkin et al. (2018) suggest that technical implementation runs in parallel to interaction design, as this would quickly flesh out whether certain interactions are technologically feasible to implement or need adaptations. A limitation of this methodology is that it was applied to adapting existing commercially available social robots, and not in the development of entirely new robots. This could explain why the methodology does not include design considerations of appearance or mechanical properties beyond choosing an existing platform that meets the requirements defined in initial context exploration and need-finding stages.

Combining the UX of HRI design methodology (Tonkin et al., 2018) with a research through design approach, Khan and Germak (2018) collaborated with a telecommunication company

[1]**Lean UX** is an approach to designing products (primarily software products) within agile development teams. It builds on traditional ways of working with UX, Design Thinking, and adopts principles from agile development. Consequently, Lean UX is an approach to UX which better matches the speed of agile development while opening up the design process to non-designers and rejecting the idea of 'hero' designers working in isolation (Gothelf & Seiden, 2016).

to design and develop a service robot for the company's workspace. The physical design of the robot considered the context where the robot is to be deployed by resembling the building architecture and interior. Likewise, ergonomic design considerations related to the placement of the robot's touchscreen were also made. As for designing the graphical user interface of the robot, Khan and Germak (2018) took inspiration from Google's Material Design arguing that users would find it familiar and thus require less training in order to interact with the touchscreen. However, authentic users were not involved in the design of the physical appearance of the robot until a prototype was built and ready to be evaluated. Khan and Germak (2018) used observations and the Godspeed questionnaire (Bartneck et al., 2009) to evaluate usability and UX. Although the Godspeed questionnaire assesses relevant robot attributes (anthropomorphism, animacy, likeability, perceived intelligence, perceived safety), Bartneck et al. (2009) intended it for measuring users' perception of robots, which is not the same as assessing usability, UX, or to what extent the robot fulfills user needs.

Weiss et al. (2011) developed the USUS evaluation framework to account for HCD in HRI targeting humanoid robots that interact explicitly with people. In the USUS evaluation framework, usability, social acceptance, user experience, and societal impact are assessed through methods (e.g., observations, interviews, surveys) deemed most appropriate for the given factor. Weiss et al. (2011) propose that the USUS evaluation framework can accommodate traditional HCD cycles (9241-210:2019, 2019; Y. Rogers, Sharp, & Preece, 2011), where the need to apply USUS is determined at the outset of the design process. Once the requirements are specified and the authentic users and context of use are understood, Weiss et al. (2011) suggest evaluating existing platforms to establish a baseline to which novel designs can be matched. While the USUS evaluation framework provides a holistic approach to evaluating social robots, it is extremely comprehensive and time consuming to apply if all factors are to be covered, especially seen from an industry perspective where there might not be sufficient resources to UX. Wallström and Lindblom (2020) extended the original USUS framework to encompass *goals*. A UX goal is the high-level objective that the robot should meet and the experience it should evoke in its users. These goals can be extracted from corporate policies and product requirements, and should be used as metrics by robot design teams to stay on track throughout the design and development process. UX goals can be used as benchmarks for product comparison and design alternatives. However, according to a robot developer, the UX Goals evaluation method does not easily integrate with development practices, which follow predefined checklists, making the proposed framework too abstract to be applied in an industrial setting (Wallström & Lindblom, 2020).

In summary, HRI design frameworks that incorporate universal design practices, aspects of behavioral robot design, and UX can be utilized by cross-functional teams, including participation of industry partners. The exemplified frameworks were applied to existing commercial robots (Tonkin et al., 2018; Axelsson et al., 2021), concluded with a proof-of-concept and a functional prototype (Khan & Germak, 2018), or remained on a conceptual level (Weiss et al., 2011; Wallström & Lindblom, 2020) but have not been trialed in the development of entirely new commercial robots. Despite the participation of industry practitioners in evaluation of the design frameworks, industry development practices have not been accounted for. Instead, these frameworks foreground design–which is a good thing–but seem to overlook the context where the framework will be applied, and that is within a business context together with developers potentially following stricter development paradigms, as mentioned by a robot developer in (Wallström & Lindblom, 2020).

2.1.4 Summary

These frameworks vary in granularity and provide valuable considerations to the design of physical, embodied robots that are supposed to enter social contexts and interact with people. The robots designed in these studies are either prototypes used for research purposes or proof-of-concepts, or commercially available robots, which require new customized software to make the robot operate in the desired manner given the context of use, consequently leaving little to no room for adjustments and modifications to the robots' exterior and movement capabilities. As have been previously established in this dissertation, three major gaps in the field of HRI are that the literature does not sufficiently cover industry robot designers' requirements for HRI design frameworks, their development practices outside academia, nor the organizational mechanisms that influence UX integration in robot development and adoption in robotics companies. This makes it difficult to discern how these HRI design frameworks enable robot design teams to progress beyond prototyping and evaluation of high-fidelity, functional prototypes to actual development and implementation as well as how such frameworks would work within a business setting together with industry development practices in the context of developing entirely new robots. Results from HRI research have been criticized for not easily translating into practice because it is separated from real-world deployment of robots, which require close attention to detail, reliability, and robustness (Cila et al., 2024); aspects not considered in the HRI design frameworks presented in this dissertation. Addressing the aforementioned gap is therefore critical if researchers want to provide industry practitioners with practical applicable research-based guidance on how to integrate and adopt UX.

According to Buchner et al. (2012), researchers should strive towards influencing practices and doing so require that we first understand the situation and its constraints. Similarly, Wallström and Lindblom (2020) stress the importance of collaborating with practitioners who are expected to utilize HRI design frameworks to ensure that they are appropriate for industry and commercial use. Such collaboration is at the core of this dissertation. This dissertation posits that HRI design frameworks should be adapted to support and fused with existing industry practices, rather than replacing them. Furthermore, integrating UX, according to Wallström and Lindblom (2020, p. 197), requires "substantial changes in the existing robot development processes, which also poses changes in existing mind sets". This issue has not been addressed in HRI literature, yet it has been studied extensively for UX integration in software development, which is covered in the following section.

2.2 UX within Agile Software Development

Despite some valuable examples of HRI studies being conducted within or together with robotics companies (not within manufacturing industries), these studies demonstrate how company employees anthropomorphize the robots they develop (Chun & Knight, 2020); how a UX of robot methodology was applied to identify commercial applications of an existing commercially available social humanoid robot (Tonkin et al., 2018); how to work with formative usability evaluation during robot development (Zhong & Schmiedel, 2021); and how robot design guidelines can be developed and communicated to robot developers (Cila et al., 2024). However, they do not address the actual development context of the robot and the possible mechanisms at play that may influence how UX is integrated and adopted in the company. This section therefore focuses on UX integration within agile software development from a process perspective and builds on experiences reported in literature about how the integration materialized, rather than focusing on the products and solutions themselves. To set the scene, the section first briefly introduces principles of **agile** development. Afterwards, the section covers several challenges with integrating UX with agile.

2.2.1 Principles of agile development

The agile manifesto describes four principles of agile development (Beck et al., 2001):

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Effectively this means that satisfying customers through continuous delivery of software is of highest priority and, by promoting just-in-time development, agile welcomes discovery of new and changes to pre-established requirements (Beck et al., 2001). Agile development is an alternative to traditional waterfall development, where requirements are gathered and features defined before moving to the design phase, with implementation and quality assurance as subsequent phases with no iteration between phases and where implementation would often begin before the design phase (Sy, 2007). Moving away from this approach, agile breaks down product development into incremental releases that are worked on during a set period of time, which is called a **sprint**, by self-organizing teams working in supportive environments. While the agile manifesto prescribes a close collaboration between business people and developers (Beck et al., 2001), there is no mention of the role of UX nor authentic users. Consequently, agile development does not have the necessary infrastructure to support most UX work, which is often carried out through in-depth user studies, which in turn does not match well with the rapid pace of agile development (Wale-Kolade, Nielsen, & Päivärinta, 2013). Even so, integrating UX into agile software development results in better-designed software than what was possible using waterfall approaches (Sy, 2007). Organizations may claim to do agile development (Øvad & Larsen, 2015), but in practice it may be more akin to what Gothelf and Seiden termed **agile fall** which is:

> "[...] the combination of an up-front design phase that results in work that is handed off, waterfall style, to an engineering team to then break up into stories and develop in an 'agile' way" (Gothelf & Seiden, 2016, p. 146).

As mentioned, agile software development teams produce small, incremental batches of working software which break down the product, in some cases, to a feature level. However, such breakdown can be damaging to UX that requires careful consideration to deliver a unified and coherent experience (Kashfi et al., 2017; Larusdottir, Gulliksen, & Cajander, 2017). If UX is included in agile software development, it is often allocated limited resources, possibly because UX is not explicitly incorporated into agile practices such as scrum (Law & Lárusdóttir, 2015). To increase the uptake of UX in agile software development, Sy (2007) 1) introduced a separate pre-development phase called **sprint 0**[2] that focused on gaining a deep user understanding to guide subsequent development; 2) introduced flexible chunking (also called time-boxing) of UX activities, where the design was broken down into smaller and more manageable chunks that were accommodated within a sprint; 3) communicated early and frequently the design vision to improve the workflow between UX specialists and developers; and 4) conducted discount usability tests where compromises were made regarding the number of participants and use of 'proxies' (i.e., a person preferably with deep knowledge about users) to better fit the rapid pace of agile development. While **sprint 0** work well in software development, it may need to be rethought for robotics. Physical product development requires longer lead times for prototyping, manufacturing, and safety testing. This temporal mismatch between software and mechanical development cycles creates unique challenges for UX integration in robotics that are not addressed by traditional agile practices.

Furthermore, integrating UX in agile software development is vulnerable to individuals, organizational factors, and external events. Changes in the market–customers not wanting to pay for upfront design activities because they increasingly take care of such activities in house–can lead to separation between UX specialists and software developers as they became

[2] **Sprint 0** is sometimes referred to as **cycle 0** or **upfront design** which I return to later in this chapter.

more reactive to customers' demands (Persson, Bruun, Lárusdóttir, & Nielsen, 2022). While software developers can benefit from adopting agile, there might be companies and business units who struggle to exploit agile practices (Persson, Nielsen, & Bruun, 2018). For example, agile practices in companies developing physical products with embedded software might reflect **agile fall** as a result of how physical parts of a product is developed, namely through stage-gate models, which resemble the waterfall approach (Øvad & Larsen, 2015). Merging physical product development with agile development practices can lead to suboptimal design decisions. That is, it is cheaper and faster to add a feature, which does not appear to be relevant given user requirements, to a physical button than to manufacture an entirely new mold without the physical button (Øvad & Larsen, 2015).

2.2.2 The meaning and value of UX

There are different perspectives concerning the meaning and value of UX. Lack of consensus on what UX means, its underlying constructs, and its value are recurring issues when integrating UX in organizations. This was, for example, evident in customer requirements that vaguely specified the kind of experience they wanted (e.g., 'cool', 'fun', or 'high-tech') (Kashfi et al., 2017). Extending this, Kashfi et al. (2017) posit that, while the industry has developed a better understanding of what usability is, the same does not apply to UX. However, Øvad and Larsen (2015) found that practitioners gained a more nuanced understanding of UX over a two year period, which aligned more closely with definitions of UX (Hassenzahl & Tractinsky, 2006; 9241-210:2019, 2019). Even so, stakeholders continue to prioritize the pragmatic and functional aspects of a product, as well as objective and measurable characteristics, while overlooking the emotional, hedonic, and subjective aspects of users' experiences and interactions, as well as the relationships between those aspects (Kashfi et al., 2017).

Value and importance ascribed to UX is higher when a product has competitors and goes directly to its users, whereas for technology-centered and Business-to-Business (B2B) companies, functionality often trumps UX (Kashfi et al., 2017). Also, the value and importance of UX seem dependent on managers' preferences, values, and motivations (Kashfi, Feldt, & Nilsson, 2019). Practitioners often talk about UX from a business perspective, rather than a user perspective, to increase the chance of UX services playing a role in product development (Kashfi et al., 2017). However, if UX aspects are not explicitly mentioned in a project brief or the requirements documentation, practitioners may be reluctant to work on UX, because it is seen as an additional service that they will not be paid to deliver (Ardito, Buono, Caivano, Costabile, & Lanzilotti, 2014).

User needs and insights can contradict or conflict with business goals and the assumptions held by internal stakeholders at high managerial or executive level even at the most human-centered organizations. In those cases, UX specialists must manage stakeholders' assumptions, business needs, and authentic user needs. Formulating easily testable hypotheses helps teams to efficiently evaluate whether their assumptions about users, products, and business growth are accurate, aiding management and communication around project progress (Krout, Carrascal, & Lowdermilk, 2020; Gothelf & Seiden, 2016). Likewise, consensus-building techniques such as affinity maps, dot voting, and forced ranking help teams prioritize content and system functionality, but require validation with users (Levy, 2021). Moving from the traditional 'feature roadmap' that many scrum teams work with to 'problem roadmap', which is a characteristic of Lean UX, supports communication between teams and stakeholders, especially with regard to ongoing problem solving (Gothelf & Seiden, 2016).

2.2.3 UX as a shared responsibility

Designers are too often asked to create specific design outputs (e.g., wireframes) and their participation in product development is often limited to strictly design aspects, thereby constraining their effectiveness, influence, and scope of their work while enforcing siloed teams (Gothelf & Seiden, 2016). Because the role of UX is not explicitly incorporated into scrum, UX specialists may feel out of touch with the team culture (Larusdottir et al., 2017). Improving UX work requires that UX specialists are involved continuously and throughout the entire design process; limiting UX specialists' involvement to defining product requirements risks that UX will be detached from the project, whereas involving UX specialists only in the late stages diminishes their impact on the product (Kashfi et al., 2017). However, continuous involvement can be misinterpreted as UX specialists assuming full control of the project, resulting in a power struggle between UX specialists and non-UX professionals (Kashfi et al., 2017). While the literature often portrays the scenario of developers being reluctant to collaborate with UX specialists and implementing user insights, Ferreira et al.'s (2011) study showed the opposite. Developers did not want to proceed with implementation based on their own UX design before the plans were vetted by UX specialists to avoid possible corrections at a later stage. Instead of making their own design decisions, developers spent time searching for and involving a UX specialist. However, in this specific case, UX specialists and developers were separated, because a UX manager wanted to "protect" the UX team from having to deal with developers (Ferreira et al., 2011). This study thus demonstrates that UX should be a shared responsibility: while UX specialists may not rely on developers to make design decisions, developers rely on UX specialists to make decisions about implementation that align with the design decisions.

To overcome separation between UX specialists and non-UX professionals, UX specialists should ideally have a breadth of competencies enabling them to collaborate and communicate with developers and marketers, while accounting for technical feasibility and business goals (Kashfi et al., 2017). This is why UX should be a shared responsibility (Kashfi et al., 2017) that is orchestrated and facilitated by UX specialists (Gothelf & Seiden, 2016), who should have the authority to influence project planning if the UX is not satisfactory (Larusdottir et al., 2017). Furthermore, simplifying the test environment, e.g., by enabling remote observation, positively impacts collaboration as it spreads a deeper understanding of users across the organization (Gothelf & Seiden, 2016). Extending this, having the entire team observing tests reduces subsequent debriefing activities (Gothelf & Seiden, 2016) and fosters empathy and co-ownership (Krout et al., 2020). Companies can additionally benefit from assigning smaller UX activities, such as observations and A/B testing, to developers (Øvad & Larsen, 2015), particularly if the need for UX is greater than what the available UX specialists can deliver. To further promote UX as a shared responsibility, it is beneficial to have UX specialists work in close physical proximity to developers, which also improves collaboration and communication (Persson et al., 2018). Close collaboration between UX specialists and developers–not necessarily mediated by physical seating arrangement–increases mutual awareness of the type and scope of work each profession delivers and its impact, such that the team can make informed judgements around coordination (Ferreira, Sharp, & Robinson, 2012). As distributed teams are becoming increasingly common in software development companies, it is important to note that contextual factors play a larger role in collaboration and communication between UX specialists and developers than the physical location itself (Da Silva, Silveira, Maurer, & Silveira, 2018). Thus supporting UX integration in agile requires that distributed teams utilize online tools.

2.2.4 UX and upfront requirements

Functional requirements are often established prior to requirements addressing UX. From a project management perspective, involving users in the requirements phase could increase the cost of the project (Kashfi et al., 2017). Practitioners may additionally be reluctant to involve users in the requirements phase due to previous experiences with users who were unaware of their needs, unable to articulate them, or requesting too much (Ardito et al., 2014). Scrum teams might be less responsive towards changing requirements once a sprint has commenced, resulting in customers having to wait at least one sprint before developers can start addressing the changed requirements (Law & Lárusdóttir, 2015). However, only having to wait for subsequent sprints is a big improvement compared to traditional waterfall approaches, where requirement changes were not welcomed and would be comparatively costly to implement. Agile approaches reduce the need for upfront activities (Da Silva et al., 2018) and place a stronger emphasis on customers prioritizing what gets implemented than on user insights (Fox, Sillito, & Maurer, 2008). Contrarily, incorporating upfront design activities results in a deeper understanding of users and context (Wale-Kolade et al., 2013). **Upfront design** covers requirements specification, preliminary sketches, and wireframes based on, e.g., contextual inquiry. By collaborating with system architects, upfront design activities can in fact reduce development risks (Persson et al., 2018; Salah, Paige, & Cairns, 2014; Persson et al., 2022).

This is because upfront design activities provide UX specialists with knowledge of whether requirements change, which the UX specialists then coordinate with the system architect how to address in terms of implementation (Persson et al., 2018). Establishing a product vision in the upfront design activities helps UX specialists maintain an overview of the whole system, as creating wireframes–beyond that of designing smaller details–can be challenging once development has commenced (Persson et al., 2022). If developers are not part of these upfront design activities, there is a risk that they become passive consumers of UX information (resulting in decreased engagement with UX) and that UX specialists propose designs that are not technically feasible to implement (Zaina, Sharp, & Barroca, 2021).

Upfront design can be supplemented by work-in-parallel, where developers build software that satisfies the specifications from upfront design activities, which is then evaluated between sprints with customers or users (Wale-Kolade et al., 2013) and approved by UX specialists (Persson et al., 2018). This is seen as a way to guard developers from having to cope with continuously changing requirements (Persson et al., 2018). Meanwhile, UX specialists begin their work for upcoming sprints (Persson et al., 2022; Sy, 2007). There is a financial benefit to work-in-parallel, because while UX specialists are dedicated full time to upfront design, their role fades out during development, which implies that they can support multiple development teams (Persson et al., 2022). To reduce the risk that UX becomes detached from development by working in parallel, it is necessary to establish some synchronization, for example by ensuring that UX specialists attend daily scrum meetings, maintain daily communication with developers, and visualize UX work (Salah et al., 2014).

2.2.5 Artefacts supporting collaboration and communication

For visualizing UX work in agile development, artefacts such as sketches, wireframes, personas, and especially prototypes and user stories support smoother communication between practitioners (Garcia, da Silva, & Silveira, 2017). Wireframes and prototypes support communication and validation of ideas particularly–but not exclusively–during discovery phases and planning events (e.g., sprint planning), while user stories clarify implementation tasks and enable developers to estimate required development efforts (Garcia, da Silva, & Silveira, 2019). Additionally, user stories help determine if a feature will deliver value to users (Garcia et al., 2019). User stories are typically defined as: 'As a [**type of user**], I want to [**accomplish something**], so that [**some reason**]' (Cohn, 2004; Gothelf & Seiden, 2016). According to Ananjeva et al. (2020), the way user stories are utilized can indicate how well UX is incorporated into agile development. That is, verbose user stories indicate underlying collaboration and communication issues between UX specialists and developers, and are seen as a defensive mechanism to maintain professional pride, whereas concise user stories indicate a smoother integration of UX in agile (Ananjeva et al., 2020).

There has been an increase in digital tools that can support UX specialists in a variety of tasks, e.g., wireframing, remote testing, and online co-design. However, these tools can increase workload and result in breakdowns, errors, fatigue, and stress from managing a large set of tools and embedding them into the company's existing software ecosystem and established work practices (Fedosov, Boos, Schmidt-Rauch, jarno Ojala, & Lewkowicz, 2021). This increase in available UX tools can result in UX specialists developing a personal preference for certain tools, which can negatively impact collaboration with developers, as developers would have to adjust depending on who they are collaborating with (Persson et al., 2022).

2.2.6 Access to authentic users is not a given to UX professionals

The degree of user involvement hinges on gaining access to users (Kashfi et al., 2017; Ardito et al., 2014). However, access to authentic users may in some cases require the client to facilitate that access, which they may not be willing to do because of doubts about the value of UX insights, non-disclosure agreements, and additional costs. Even if the client is willing to gather user feedback, the validity of such feedback may be compromised and modified to support the client's own interests (Law & Lárusdóttir, 2015; Svanæs & Gulliksen, 2008). While exposure to authentic users increase sensitivity towards users' needs in development (Gothelf & Seiden, 2016; Krout et al., 2020), neither agile nor scrum facilitate direct contact between developers and authentic users because that contact is mediated by a product owner. Consequently, developers are protected from interruptions such as requirements changes (Law & Lárusdóttir, 2015; Larusdottir et al., 2017). The rapid pace of agile poses severe challenges in scheduling time for authentic user feedback (Salah et al., 2014). One strategy to mediate this challenge is to reserve authentic users for in-situ validation of designs later in the product development cycle, which can only be validated by authentic users, and recruit proxies for validating operation-level tasks (Sy, 2007).

Nevertheless, it is common practice to have some kind of discovery and need-finding phase that focuses on understanding users, which informs user requirements, e.g., based on personas and user stories. Accordingly, collaboration between stakeholders, designers, and developers in the discovery phase contributes to a shared product vision, which increases the probability that the product will succeed (Levy, 2021). However, if authentic users are only involved in the discovery phase, there is risk that their needs are replaced with product owners' or client's assumptions of what they need, leading authentic users to refuse to partake in similar activities (Svanæs & Gulliksen, 2008). Additionally, when product and development teams become too attached to the product, there is a risk that they undermine user needs if they challenge or conflict with the teams' own views (Ananjeva et al., 2020).

2.2.7 Summary

The related work presented above outlined barriers preventing UX from being integrated in agile software development. The discussed examples can carry implications for the way robotics companies develop robots and, consequently, how we can support integration and adoption of UX. Most notably, the combination of agile software development with physical product development, which rely on stage-gate models such as New Product Development [3], can result in suboptimal design decisions (Øvad & Larsen, 2015; R. G. Cooper, 2014). That is, the typical two-week sprint cycles common in software development do not align with the longer mechanical development timelines. While software updates can be implemented rapidly and deployed continuously, changes to physical components require substantially more time, resources, and planning. Furthermore, manufacturing and supply chain dependencies introduce complexities that affect development cycles in ways not experienced in pure software development. Consequently, mechanical designers may be rushed to make design decisions that are economical and allow them to keep up with the pace of agile software developers, and those decisions may not favor users' needs.

These issues might also carry implications for the collaboration between developers and UX specialists. For example, some software developers might refuse to collaborate with UX specialists and implement user insights, while others delay implementation until a UX specialist has vetted the design to avoid rework (Ferreira et al., 2011). The collaboration between developers and UX specialists is critical in robot design because post-launch changes to robots are expensive, and often require more than pushing a new software update. Upfront design, which ideally includes context exploration, engagement, and co-design sessions with authentic users to prototype relevant robotics concepts–as illustrated in the universal design practices applied in HRI–is crucial in robot design, as it reduces development risks (Persson et al., 2018; Salah et al., 2014; Persson et al., 2022).

The literature on UX within agile software development demonstrated the ongoing debate of what might be expected of UX specialists in terms of competencies and responsibilities. On the one hand, UX specialists' responsibilities might be limited to creating specific design outputs, which has implications on their effectiveness, influence, and scope of their work (Gothelf & Seiden, 2016). On the other hand, UX specialists should ideally have a breadth of competencies enabling them to orchestrate and facilitate UX work (Gothelf & Seiden, 2016) as well as collaborate and communicate across various disciplines, while accounting for technical feasibility, business goals, stakeholders' assumptions, and authentic user needs (Kashfi et al., 2017; Krout et al., 2020; Gothelf & Seiden, 2016). Orchestration and facilitation are

[3] Stage-gate models, such as New Product Development (NPD), comprise of a set of gates with accompanied stages. Cooper (1988, 1990, 2014) outline the NPD process in more detail, but generally it includes the following gates: initial screening, preliminary assessment, pre-development business analysis, pre-test review, pre-trial review, and pre-commercialization business analysis (R. G. Cooper, 1988).

necessary competencies for UX specialists who want to open up the design process through thoughtful design management, which is the topic explored in the following section.

These issues collectively suggest that robotics companies need adapted approaches that can effectively balance agile principles with the constraints inherent to physical product development. Such approaches must acknowledge that robot development cannot match the rapid pace of agile software development while maintaining a human-centered focus.

2.3 UX Strategy meets the Organization

The previous section looked at UX integration in agile development and outlined barriers UX specialists have been confronted with. Those examples highlighted some challenges with embedding UX in agile software development based on broader organizational perspectives, but did not sufficiently account for corporate culture or design management. The organizational aspects of UX integration are particularly complex in robotics companies due to their hybrid nature. Unlike pure software companies or traditional manufacturing firms, robotics companies must integrate and adopt UX across vastly different disciplines, each with their own established processes, tools, and professional cultures. The mechanical teams often follow stage-gate processes with long development cycles, while software teams may adopt agile practices with rapid iterations. UX must bridge these different paradigms while also addressing the unique challenges posed by robots' physical embodiment and autonomous capabilities. This complexity means that organizational UX strategy in robotics cannot simply apply approaches that work in software companies–it requires careful consideration of how to coordinate UX across mechanical, electrical, software, and systems engineering teams.

Corporate culture reflects "the way it is around here [i.e., within the company]" (Rosenberg et al., 2015, p. 175) and is typically formed by founders and executives. In many large established companies, the culture is either obstructive or destructive to inherent HCD approaches such as Design Thinking (Rosenberg et al., 2015). Consequently, corporate culture can pull employees back to familiar routines at the expense of users. However, if corporations manage to integrate Design Thinking in corporate culture, they can gain competitive advantage, but it requires that Design Thinking is embedded throughout the business culture, processes, practices, systems, structures, and strategies, and not just appended to product development (Rosenberg et al., 2015; Brown, 2019). I argue that this applies to UX as well.

In this dissertation, **design management** is understood as "[...] the ongoing management–and leadership–of design organizations, design processes, and designed outcomes (which include products, services, communications, environments, and interactions)" (R. Cooper et al., 2009, p. 50), and deals with "the (strategic) selection and mobilization of sets of activities, practices, capabilities, and (organizational) resources necessary for [a] product to be developed"

(Carneiro et al., 2021, p. 198). Design management includes and moves beyond product design to also encompass the strategic scaling of design across an organization (Carneiro et al., 2021; Chiva & Alegre, 2007); this is an area of research that has received little attention in HRI. Considering the definition of UX strategy provided in the introduction, design management and UX strategy are heavily intertwined; both are crucial to effectively support multidisciplinary teams as they collaborate and coordinate (Carneiro et al., 2021).

2.3.1 Organizational support for in-house UX

Organizations may not allocate sufficient resources to support UX during agile development. This may be a result of how UX services are negotiated between a software provider and its client, as UX is often seen as an extra expense which has to be covered by the client or the development budget (Kuusinen & Väänänen-Vainio-Mattila, 2012). Consequently, if the client does not provide UX goals or requirements, then the project team is less likely to invest resources in designing for good UX. If clients do not want to pay for UX services, it can discourage companies from investing in in-house UX. At the same time, creating UX teams in-house is only one step towards creating a UX-focused organization. This is not a trivial matter as it requires a fundamental shift in organizational practices, which organizations may be unable to create and sustain for a variety of reasons (e.g., lack of understanding, inability or unwillingness to support UX, staff turnover, or changes in leadership) (MacDonald, 2019). Even if a company hires UX specialists, the organization may not be ready to support them in maximizing value. This can lead to clashes between UX specialists, product managers, and product owners with regard to who "owns" UX; especially if their roles and decision-making power have not been sufficiently clarified (Kashfi et al., 2019). Similarly, even if the organization has a dedicated UX team, there may not be enough UX specialists to support the number of project teams. Consequently, project teams may not receive the UX support when needed because UX specialists are overworked, leaving developers in charge of UX decisions (Kuusinen & Väänänen-Vainio-Mattila, 2012).

In companies with minimal to no design management, UX specialists spend considerable time educating peers and managers by, e.g., sharing books and articles, facilitating workshops, or mentoring colleagues (Gray, Toombs, & Gross, 2015). Thus, a design culture and management may hinge on what the individual brings to the table. According to Rohn (2007), UX specialists focus so much on understanding user needs that they tend to forget the needs of internal stakeholders, from whom they need to ensure buy-in and support. The value company executives assign UX is reflected in where UX is positioned in the company regarding the reporting level and department (Rohn, 2007). Ideally, UX as a department should be positioned at the same level as marketing and development. Because UX rarely has a seat at the executive table, Rohn (2007) argues that centralized UX teams that matrix their resources (i.e., allocate team members to different business units) perform better in terms of efficiency, personal development, and career growth, produce higher quality work, and attract and retain talent better than decentralized UX teams. The financial resources assigned to UX should ideally come from a single funding source or a set percentage from each business unit, such that project teams do not perceive UX as an additional cost (Rohn, 2007).

Organizations without sufficient in-house UX competencies can outsource UX to consultancies specializing in UX or collaborate with researchers. Outsourcing UX can facilitate the UX integration process because external UX consultants bring with them a set of methods, tools, and techniques which they introduce to the organization (Carneiro et al., 2021). On the other hand, outsourcing UX poses a risk that the outcome of such work will not be sufficiently diffused in the company, but will stay with a limited number of people, thereby making UX vulnerable to organizational (in)stability caused by structural changes and staffing (Svanæs & Gulliksen, 2008). Gothelt and Seiden (2016) argue against outsourcing discovery phases (i.e., initial context exploration) as it reduces the value, wastes time, limits team-building, and imposes an additional layer of interpretation.

Organizations may not sufficiently invest in maturing their in-house UX competencies, presumably because they do not see the strategic and business value of UX (Kashfi et al., 2017). UX methodologies beyond basic tools and methods (e.g., interviews and observations) are often unknown to practitioners, resulting in ad-hoc approaches to gaining knowledge within UX. Practitioners may consequently lack the skills to carry out UX evaluations based on hedonic and emotional aspects of UX, which fall outside of the traditional evaluation methods, and account for the fact that UX is influenced by context and may change over time (Kashfi et al., 2017). Industry practitioners have pointed out the lack of suitable evaluation methods with high benefit-cost ratio (Ardito et al., 2014). In fact, UX methodologies are often considered too research-oriented and, consequently, less applicable to agile development (Larusdottir et al., 2017) and rarely followed rigorously by practitioners (Ferreira et al., 2011). It is therefore important to help practitioners identify possible adjustments and trade-offs that can be made to methods and processes without compromising the validity of findings, thereby allowing for some flexibility. Thus, we need to understand the practices that our methodologies are supposed to support (Ferreira et al., 2012), which calls for a close collaboration between researchers and practitioners.

2.3.2 Organizational shifts towards a UX-focused organization

Companies with longstanding industrial and engineering cultures are increasingly required to undergo digital transformations and in doing so, they are required to incorporate software as part of product development and services to meet increasing customer and user demands (Liikkanen, 2016). For these companies such transition might be difficult due to habitual practices and legacy culture. In this context, there is a need for organizational shifts towards strategic UX, which will enable practical UX (Liikkanen, 2016). This section presents three ways an organization can build its design culture and management, which are potentially relevant to robot design. The first focuses on the importance of involving practitioners in the transition towards a more UX-focused robot design process (Seidelin, Sivertsen, & Dittrich, 2020). The second, Lean UX–which is embedded in the UX of robots methodology (Tonkin et al., 2018)–takes a team level perspective regrading process, culture, and management. The third emphasizes the importance of considering both individual and organizational perspectives when building and sustaining a UX culture (MacDonald, 2019). These approaches can be seen as complementary due to their orientation towards different organizational levels.

Building an organization's design culture requires that employees are involved in 1) appropriating design tools and methods, as this helps form local conventions when adopting new design practices, and 2) several design initiatives whereby employees learn to adapt and apply design tools and methods, as well as contribute to scaffolding (Seidelin et al., 2020). Building a design culture additionally requires that employees are involved in 3) developing and continuously updating a common, contextualized knowledge base to support competence development (Seidelin et al., 2020).

Lean UX is a combination of a **process change** for designers and product teams; **cultural change** that makes product teams humble because they should acknowledge that their initial solutions will probably be wrong and thus require that they use many sources of insights to continuously improve their thinking and the product; and a **management tool** to organize and manage software design and development teams to become more inclusive, collaborative, and transparent (Gothelf & Seiden, 2016). It is based on UX, Design Thinking, agile development, and Lean principles (build-measure-learn loop and minimum viable product (Ries, 2017)). Lean UX is primarily intended for software solutions because building software allows for continuous design, operation, and optimization as long as it makes economic sense (Gothelf & Seiden, 2016). While robots can be thought of as embodied software solutions, they have an end state, thus not all Lean UX principles are likely to work in context of robot design. For example, it is highly unlikely that robotics companies are able to push updates on a weekly or bi-weekly basis, which is possible for purely software-driven products.

Nevertheless, Gothelf and Seiden's (2016) guiding principles regarding team configuration, culture, and process might still be relevant for instilling changes to management, culture, and process that are conducive to UX in context of robotics. Team organization is a fundamental aspect of managing Lean UX. A well-established Lean UX team is cross-functional, small, dedicated, and collocated because cross-functional teams deliver better solutions and communication, focus, and camaraderie arise from small, dedicated, and collocated teams. It is self-sufficient and empowered in that the team should be well resourced to operate without external dependencies, and is problem-focused rather than focused on delivering certain features (Gothelf & Seiden, 2016). Following best practices of team size may be challenging in robotics because additional competences are needed, and this may have implications for robot design teams' ability to coordinate and communicate efficiently.

The cultural aspects of Lean UX encourage teams to move from doubt to certainty through experimentation as they work towards an outcome–as opposed to outputs such as a feature–i.e., a "meaningful and measurable change in customer behavior" (Gothelf & Seiden, 2016, p.12). In that process, removing waste, i.e., anything that does not contribute to the ultimate goal, is key and so is forming a shared understanding of the space, product, and customers. Since Lean UX is a collaborative effort, team cohesion is above individual "rock stars", "gurus", or "ninjas" as they can be damaging to the project (Gothelf & Seiden, 2016). Lastly, permission to fail is an important cultural aspect of Lean UX, and team members should be allowed to fail without being penalized. Embedding these cultural aspects in robot design teams might enable these teams to move faster from idea to validated robot concepts that are meaningful to authentic users before moving to implementation and production.

The six guiding principles of a Lean UX process are: **work in small batches to mitigate risk** rather than sit on a large inventory of untested assumptions; **continuous discovery** by engaging customers frequently to validate product ideas; **GOOB: the new user-centricity** refers to 'getting out of the building' and engage with customers and users; **externalize your work** to share information and form ideas; and **making over analysis** or, in other words, creating over debating as this principle refers to materializing ideas so that they can be tested, rather than being debated in meeting rooms without users (Gothelf & Seiden, 2016). Finally, **getting out of the deliverable business** and focus on the outcomes achieved by teams (Gothelf & Seiden, 2016). These six principles are highly relevant in robot design, as they can minimize development risks. That is, these principles emphasize the importance of frequently engaging with authentic users and the context where the robot is supposed to operate. While there is value in analyzing user insights, Lean UX suggests that there might be more value in 'making' and experimenting (Gothelf & Seiden, 2016). This is important to consider in robot design as adopting this principle might enable, e.g., mechanical teams to match the pace of agile software developers, who work with small, incremental batches.

MacDonald (2019) proposes the User Experience Capacity-Building (UXCB) framework to support organizations in building and sustaining a UX culture. This framework is structured around conditions, strategies, and outcomes. **Conditions** are related to ensuring buy-in and support from management and defining organizational needs and goals (i.e., why the organization wants to build its UX capacity) (MacDonald, 2019). Conditions drive the strategies an organization needs in order to build UX capacity. **Strategies** are divided into *activities*, *content*, *implementation*, and *resources*. *Activities* refer to training workshops, technical assistance, hiring, team building and configuration, events, broadcasting, as well as guides, tools, and frameworks (MacDonald, 2019). *Content* must be targeted the organizational context and the challenges they face, whereas *implementation* relates to how content is shared across the organization and the format and structure of activities (MacDonald, 2019). Lastly, *resources* encompass time, infrastructure, materials, and budget considerations (MacDonald, 2019). Ideally, these strategies lead to **Outcomes** at the *individual* level regarding attitudes, knowledge, skills, and behaviors; *organizational* level involving changes to the organization's UX practices, processes, and culture as well as changes not specifically tied to UX; and *product* level in terms of product improvements.

2.3.3 Summary

Organizational mechanisms such as corporate culture and design management are critical to consider when moving UX beyond the product level in robotics companies. However, issues arise when UX strategy meets the organization, and this section summarizes some of the barriers that influence UX adoption:

- UX services are omitted from contracts which decreases the likelihood that teams invest resources in designing for good UX (Kuusinen & Väänänen-Vainio-Mattila, 2012)
- (In)ability to sustain the fundamental shifts in organizational practices that are required to become a UX-focused organization (MacDonald, 2019)
- Unsettled 'ownership' of UX (Kashfi et al., 2019) despite UX should be everyone's responsibility (Kashfi et al., 2017)
- Lack of or poor design culture and management increase the reliance on what individuals bring to the table, which makes UX vulnerable to staff-turn-over and organizational changes (Gray et al., 2015)
- UX methods, practices, and processes rarely have a high benefit-cost ratio and they are often considered too research-oriented and less applicable in agile development environments (Ardito et al., 2014; Larusdottir et al., 2017; Ferreira et al., 2011)
- UX rarely has a seat at the executive table (Rohn, 2007)

The section presented three approaches to build a company's design culture and management. The first approach rests on involving practitioners in the transition towards a more UX-focused robot design process by including them in appropriating design tools and methods, several design initiatives where they gain hands-on experience with the design tools and methods, and developing and managing a common, contextualized knowledge base to support competence development (Seidelin et al., 2020). The second approach–Lean UX as cultural change and management tool–focuses on instilling an iterative and exploratory mindset at team level by creating collocated cross-functional, inclusive, collaborative, and transparent development teams who acknowledge that their first solution is most likely flawed and who engages directly with authentic users in order to better understand their problems and needs (Gothelf & Seiden, 2016). The third approach–the UXCB framework–stipulates that a company should understand and ensure the right conditions for building and sustaining a UX culture in order to decide on the set of strategies that would lead to the wanted changes, and determine the outcomes that the company wish to achieve from their cultural transformation at individual, organizational, and product level (MacDonald, 2019).

Building and sustaining a UX-focused corporate culture and design management that favour UX is important for robotics companies in order for them to become problem-focused rather than solution- and feature-focused. Doing so could minimize the risk that robotics companies fail in the market due to poor market fit and timing, bad UX and integration with existing workflows, and lack of understanding authentic users (Dietrich et al., 2021) and it will minimize the risk of feature creep. However, presence of in-house UX specialists allocated to robot design projects are not a given in robotics companies, which often forces those companies to involve external consultants and researchers possessing such competences in order to make the organizational conditions more conducive to UX and to purposefully design the UX of their robots. While this may come at a price–e.g., the risk of UX not being sufficiently diffused within the company (Svanæs & Gulliksen, 2008)–it also presents an opportunity for UX and HRI researchers to collaborate with robotics companies on contemporary and real-world issues. For this dissertation, it is important that my role–from a company perspective–was to orchestrate and facilitate UX integration and adoption, as well as to support UX competence development of robot designers new to UX as to increase the potential of lasting impact, rather than overtaking practitioners' responsibilities.

3 RESEARCH DESIGN

Understanding industry practices and processes is a prerequisite when the objective is to influence and change such practices (Buchner et al., 2012; McKay & Marshall, 2001; Stark, 2014; Kidd & Kral, 2005), which is one of the objectives of this dissertation. This dissertation therefore applied a pragmatic research approach to identify industry robot designers' requirements for HRI design frameworks (RQ1) and examine how organizational mechanisms influence UX integration in robot development and adoption in robotics companies (RQ2) and how robotics companies can be supported to integrate and adopt UX (RQ3).

This chapter provides an account of pragmatism and relates the core principles of pragmatism to my research. The chapter then describes the dissertation's inquiry process (which is based on Deweyan pragmatism), which includes case selection, data collection and analysis strategies. Detailed accounts of the specific methodologies are described in each of the included papers. Afterwards, the researcher's position are described, before turning to considerations regarding the trustworthiness of the research.

3.1 Pragmatism

I approach my research from a pragmatic standpoint as the entire premise of my research is predicated on making academic knowledge (or theory) applicable for industry practitioners. In the forthcoming outline of pragmatism and what implications it has had on my research, I rely on others' account of pragmatism based on their readings and interpretations of the work of the four founders of pragmatism: Charles Sanders Peirce, William James, John Dewey, and Herbert Mead. Rylander (2012) provides a detailed account of how these founders viewed pragmatism from which I am summarizing with no intend to match Rylander's level of detail. Most noticeable, in this dissertation and consequently in the considered literature, is the Deweyan approach to pragmatism.

3.1.1 Central Concepts of Pragmatism

Before providing a broad view on what pragmatism is, some of the most central concepts of pragmatism are explained to ease the readability of the forthcoming sections. Additionally, these concepts are marked in **bold**, which is done throughout the dissertation. Table 3.1 presents the central concepts and their corresponding definition or explanation. The relationship between the concepts are subsequently visualized and explained.

Figure 3.1 reflects an abductive process of how theory links to practice, which "moves back and forth between induction and deduction–first converting observations into theories and

Table 3.1: Central concepts of pragmatism.

Concept	Definition/Explanation
Abduction	"consists of generating a kind of if-then formulation, in which your reflection on the nature of the problem leads you to conclude that *if* you act in a particular way, *then* you are likely [to] produce a specific set of outcomes" (Morgan, 2014a, chap. 2, p. 6). However, "the nature of this belief changes considerably when you experience the actual outcomes of acting" (Morgan, 2014a, chap. 2, p. 2).
Theory	is conceptualizations of knowledge, beliefs, and ideas formed in specific situations and circumstances (including scientific experiments) (Morgan, 2007; Dalsgaard, 2008) making theory instrumental for practice of which it must be continuously evaluated (Dalsgaard, 2014).
Experience	"[...] is a process situated in a natural environment, mediated by socially shared symbols, actively exploring and responding to the ambiguities of the world" (Rylander, 2012, p. 14).
Inquiry	"is the controlled or directed transformation of an indeterminate situations into one that is so determinate in its constituents, distinctions and relations as to convert the elements of original situation into a unified whole" (Dewey, 1938 cited by Goldkuhl (2012, p. 139)).
Action	reflects how we act in the world in accordance to the socially shared sets of beliefs in a specific situation. Actions can therefore not be separated from the situations and contexts in which they occur and they are linked to consequences and are open to change (Morgan, 2014a).
Situation	"an assemblage of subject, context, socio-cultural constructs and technologies" (Dalsgaard, 2014, p. 150) which can be either a determinate (experienced as stable) or indeterminate situations where there is a misalignment between the components that comprise the situation (Dalsgaard, 2014).
Conflict	"denotes tension or unresolvedness in the reciprocal relations between the experiencer and the circumstances" (Dalsgaard, 2008, p. 24).

then assessing those theories through action" (Morgan, 2007, p. 71). That is, **theory** is based on prior **experience**, and in order to assess the workability (i.e., "the consequences that are likely to follow from different behaviors" (Morgan, 2007, p. 67)) of theory in practice requires **inquiry**. Through the process of inquiry a set of **actions** are enacted within a given **situation**. When that happens, a series of **effects** (or consequences) occur which the person reflects on. Misalignment between assumptions of what should happen (based on theory) and what in fact happened results in **conflicts** (also called problematic situations, which "[...] challenge our pre-formed conceptualization of the world and require inquiry and action if they are to be overcome and transformed" (Dalsgaard, 2008, p. 23)). The goal is then to assess the **qualities** of the identified and experienced conflicts in order to reach a resolution. In this

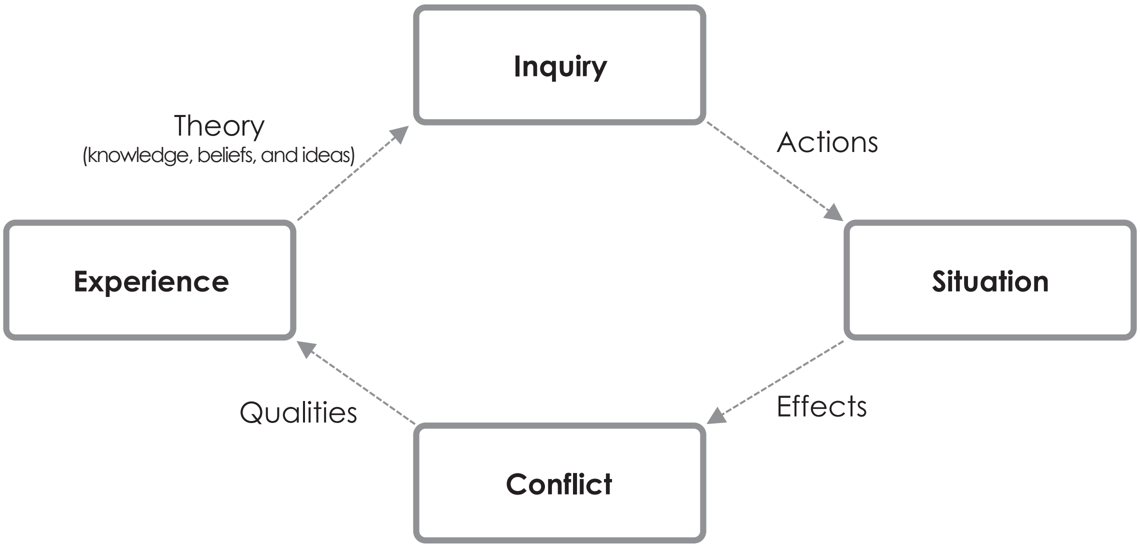

Figure 3.1: Relationship between the central concepts of (Deweyan) pragmatism. The figure is adapted from Dalsgaard (2014, 2008) where the model reflects a cyclic process where experience of conflict in a situation triggers interaction, which leads to a process of inquiry.

process, we acquire new experiences which help refine or redefine theory, and a new cycle begins to resolve indeterminate situations and conflicts. Accordingly, this process "[...] is instigated when users encounter a conflict in form of a problematic situation that challenges their preconceptions and leads them to explore and potentially affect and alter the situation" (Dalsgaard, 2014, p. 151), which require us to become creative, active agents who embrace the mutual shaping between oneself and the environment.

Seeking out **conflicts** in form of problematic situations is what enable researchers to gain new insights and expand their horizon. When we encounter these **conflicts** "we form simultaneous thought experiments with and articulations to understand what it is that makes the situation problematic. These conceptualizations form the basis for hypothesizing about how we may reconstruct or transform the situation before carrying out physical actions" (Dalsgaard, 2008, p. 23). These thought experiments are inherently difficult to trace and make visible to others before the person reaches a coherent conceptualization of a new theory. Consequently, it makes the reporting of emergent research–such as the present dissertation–challenging, because it does not follow a linear process where every aspect of the research is clear from the beginning. Thus, adopting a pragmatic standpoint is a commitment to uncertainty (Feilzer, 2010) and accepting that the world is continuous and ever-changing (Rylander, 2012). This enabled me to reassess what I thought was the problem (that the robotics industry needed a new design process) and divert my attention towards what appeared to be more relevant and pressing problems that if solved would have higher practical value for practitioners: How organizational mechanisms influence UX integration in robot development and adoption in robotics companies (RQ2) and how robotics companies can be supported to integrate and adopt UX (RQ3). Arriving at and being comfortable with pursing this direction of research were made possible by following the process depicted in Figure 3.1.

Having established these central concepts of pragmatism, it is important to understand how they evolved through the work of the four prominent pragmatic figures: Charles Sanders Peirce, William James, John Dewey, and Herbert Mead. The following section provides a broad view of pragmatism's development, highlighting the contributions of its major proponents, and how the ideas of Peirce, James, Dewey, and Mead shape the pragmatic approach used in this dissertation.

3.1.2 Broad View: Defining Pragmatism

Pragmatism emphasizes that theories must be linked to experience or practice by means of interaction and integration (Rylander, 2012). A central concept of pragmatic thought is **continuity** which "result[s] in an epistemology that departs from experience and emphasizes process and experimentation" (Rylander, 2012, p. 3) implying that 'truth' cannot be exhausted because our knowledge is never absolute as "[...] we are part of a continuously growing and transforming world" (Rylander, 2012, p. 23). Rather than being tied to ontological, epistemological, and methodological considerations, pragmatists–according to Peirce–are concerned with reflexive discussions of problems, ideas, and propositions which can be investigated through experiments in a scientific manner (Rylander, 2012). Peirce coined the term **pragmatist maxim** which is "a rule or a method for becoming reflectively clear about the content of concepts and hypotheses: we clarify a hypotheses by identifying its practical consequences" (Rylander, 2012, p. 3). Furthermore, Peirce is known for his work on induction, deduction, and abduction arguing that abduction is "the only mode of inference that can truly give rise to surprises" (Rylander, 2012, p. 7).

Offering a different perspective, James considered embodied experience fundamental to all that we know and feel, and explains pragmatism as "[...] a theory of truth wherein the 'meaning' of a concept is marked by 'some particular consequence' in our future practical experience" (Rylander, 2012, p. 12). What separates James' notion of pragmatism from Peirce's is that, according to James, "an idea's effectiveness is judged by an individual agent rather than determined objectively by a scientific community" (Rylander, 2012, p. 12). James included a more subjective viewpoint in pragmatism, which expanded pragmatism to encompass everyday life rather than tying pragmatism exclusively to science, as Peirce did (Rylander, 2012). The focus on the embodied and inherently subjective nature of experience of everyday life necessitates an appreciation of the socially, situated **situation** wherein these **experiences** occur. Whether something is true thus depends on whether 'it' works in a particular **situation**, and consequently James rejects the idea of objective truth (Rylander, 2012). According to James, pragmatism is about "interpret[ing] each notion by tracing its respective practical consequences. What difference would it practically make to anyone of this notion rather than that notion were true?" (James 1907/1995: 11 cited by Rylander (2012, p. 13)).

Dewey sought to preserve both the scientific rigor promoted by Peirce and the focus on embodied everyday experience promoted by James (Rylander, 2012). Through their friendship and collaboration, Dewey adopted the idea that **experiences** are inherently socially constructed and situated, as advocated by Mead (Rylander, 2012). Consequently, Dewey considered individual's experience to be shaped by both internal processes and the interactions with the contextual whole considering both physical and social aspects. The goal of Deweyan pragmatism is to make theory practical applicable to the concerns of everyday life *in* everyday life. Concerns about the workability of theory to address and potentially solve real, situated problems therefore weigh much higher than metaphysical considerations regarding ontology, epistemology, and methodology (Morgan, 2007). Even so, Dewey shared his thoughts on these metaphysical considerations. At the ontological level (assumptions about the nature of reality (Guba & Lincoln, 1994)), Dewey argued that "even though there is a reality that exists apart from human experience, it can only be encountered through human experience" (Morgan, 2014a, chap. 2, p. 17). Dewey further argued that "all knowledge of the world is based on experience [...] [and] all knowledge is social knowledge" (Morgan, 2014a, chap. 2, pp. 17-18), which reflects the epistemology (assumptions about what can be known about reality (Guba & Lincoln, 1994)) of Deweyan pragmatism. Lastly, at the methodological level (decisions about how to produce knowledge (Guba & Lincoln, 1994)), both James and Dewey were concerned with "why you would want to do research one way rather than another" (Morgan, 2014a, chap. 2, p. 18). Consequently, researchers are encouraged to pursue methods they deem most appropriate for the given situation as long as they are oriented towards solving practical problems in the real world and are befitting for studying the phenomenon in question (Feilzer, 2010). This latter point is what makes pragmatism particularly appealing as it allows researchers freedom and flexibility to choose, mix, and adapt methods that they deem fitting for answering a particular research question or a set of research questions.

The pragmatic approach, particularly Deweyan pragmatism, directly informed the methodological choices in this dissertation. For instance, the use of multiple data collection methods across the four papers reflects the pragmatic emphasis on methodological pluralism. The digital ethnography in Paper 2 aligns with the pragmatic focus on studying phenomena in their natural context. The case study in Paper 3 and the action research in Paper 4 embody the pragmatic principle of learning through action and reflection in real-world settings. These methodological choices were not just practical decisions, but were fundamentally rooted in the pragmatic philosophical stance adopted in this research. The following section provides an extended argumentation for the pragmatic approach taken in this dissertation.

3.1.3 Relevance of Deweyan Pragmatism to this Dissertation

In this section, I argue that Deweyan pragmatism ties nicely with the focus on UX of social service robots and that Deweyan pragmatism is particularly relevant for studying and transforming the processes and practices within organizations. The section ends with a summary of five reasons why/how Deweyan pragmatism is relevant for my dissertation.

First, as mentioned previously, Deweyan pragmatism is concerned with making theory practical applicable to everyday life and considers that embodied everyday experiences shaped by internal processes and interactions with the physical and social contexts influence both theory and action. This inert focus on embodied and socially situated experience that shape theory and action (or practices and processes) resonates with the dissertation's focus on UX of social service robots. Recalling the ISO 9241-210:2019 (2019) and Hassenzahl and Tractinsky's (2006) definitions of UX which bare credit to the influence that emotions, beliefs, behaviors, preferences, and perceptions have on a user's experience, as well as the influence that the physical and social context in which the interaction takes place in have on the user's experience. Furthermore, the HRI literature stresses the importance of acknowledging and considering that the embodied and socially situated experience people have with robots in everyday life shape how they interact and act around robots in public places, and this experience is shaped by a number of factors, including the robot's attributes, its tasks, physical and social context, prior experiences, and media (see e.g. (Šabanović, 2010; Martinez, VanLeeuwen, Stringam, & Fraune, 2023; Mutlu & Forlizzi, 2008; Yamada, Kanda, & Tomita, 2020; Satake et al., 2009; Horstmann & Krämer, 2019)). Embodied and socially situated experience is as central to Deweyan pragmatism and UX as it is to the design of social service robots, considering that a positive user experience does not occur by itself; it has to be deliberately designed for (Lindblom & Andreasson, 2016).

Second, Deweyan pragmatism resonates with the process-focus taken in this dissertation and the interest in identifying strategies (as per Levy's (2021) explanation of UX strategies) for the integration of UX in robot development and the adoption of UX in robotics companies. According to Dixon, Eklund, and Wegener (2023), Deweyan pragmatism is particularly relevant for studying and transforming processes based on participatory approaches. Lindland (2022), for example, studied how practitioners involved in product development processes developed a shared understanding of what was possible to do and how those practitioners came to an agreement of what a good, innovative product could be when it did not yet exist. Similarly, Kelly and Cordeiro (2020) studied organizational processes, specifically performance measurement and evaluation. Pragmatism enabled Kelly and Cordeiro (2020) to uncover various practitioners' interests, which–together with the literature–informed and refined the research objectives. These authors concluded that pragmatism had instrumental value to their research on organizational processes, as it relied on active participation of practitioners in order to uncover and contrast their ideas and beliefs. This argument is particularly important to this dissertation, the case study (Paper 3), and the action research (Paper 4), because the interest lied in *what* practitioners did, *how* they did it, and the mechanisms influencing *why* they did it in this way. The strong emphasis on actionable theory in pragmatism requires researchers to engage with multiple experiences of the same phenomena. I therefore considered and contrasted experiences across individuals and teams involved in the same robot development project working towards solving a unified problem. For example, I involved a wide range of people in my research, whose practices and processes would in someway be affected by changes, e.g., suggested in the action research. I sought out contributions from project managers, product managers, and practitioners responsible for UX because I expect them to be the main drivers of UX integration and adoption. Additionally, I pursued inputs from various team leaders, e.g., from mechanical, software, and hardware teams, as they coordinate and collaborate with project managers, product managers, and practitioners responsible for UX, and consequently influence UX integration and adoption.

To summarize, there are five reasons (including the two outlined above) why I find Deweyan pragmatism relevant in the context of this dissertation:

- **Choice of focus (UX of robots):** This dissertation focus on *how* industry practitioners can integrate UX in their development of social service robots that are supposed to operate in human-populated environments as professional assistive tools for operators (e.g., facility management staff) and as personal service agents for InCoPs. It is well-established that the physical and social context wherein interactions with robots take place influence people's (i.e, operators and InCoPs) experience and behavior (see e.g. (Šabanović, 2010; Martinez et al., 2023; Mutlu & Forlizzi, 2008; Yamada et al., 2020)). This was indeed the case in Paper 2 (Nielsen, Skov, Hansen, & Kaszowska, 2023).
- **Choice of focus (processes and practices):** This dissertation is distinctively interested in *how* robots are developed and the actions (processes and practices) made towards that goal, as well as the conditions resulting in problematic situations that influence *why* it is done in this way. Additionally, my research is situated within the real world and to embrace the notion that the social context influence individual's experiences and by effect, their actions, I consider the views of multiple stakeholders and how they come to terms, coordinate, collaborate, align, and influence each others' actions (processes and practices) towards their common goal.
- **Choice of research questions:** Through the process of inquiry, it is perfectly acceptable that pragmatic researchers reassess their research questions and adapt them in accordance to what is learned through the inquiries, which enable researchers to pursue new directions. That is, we might not ask the "right" or most interesting question at the outset of our research, because there are still many indeterminates, and it is therefore only

through inquiry that we can sharpen our focus and research questions. This is why I am comfortable with making a pivot from RODECA as a ***design process*** (as presented in Paper 1) to focusing on developing a deep understanding of the **situation**, i.e., *how* robots are developed, and the mechanisms that influence *why* robots are developed in a certain way, as well as *how* robotics companies can be supported to integrate and adopt UX (as presented in Papers 3 and 4).

- **Choice of methods:** Pragmatism offers the freedom to choose, mix, and adapt methods that are deemed fitting to answer the research questions. I, for example, made a deliberate choice to compute intercode reliability as part of a reflexive thematic analysis in Paper 4 (Nielsen, Ordoñez, Skov, & Jochum, 2023).
- **My own position:** Pragmatism resolves the debate about whether research is inherently objective or subjective by proposing a middle ground; intersubjectivity that allows researchers to balance the views of research participants and those of our research community. Additionally, pragmatic researchers typically take part in the phenomenon they study, thereby allowing for a mutual shaping of experiences. I account for my engagement in Section 3.2.3 and reflect on my own position in Section 3.3.

The following section provides more detail about **inquiry** as put forward in Deweyan pragmatism and explains my own inquiries.

3.2 Abductive Inquiry

This section describes what **inquiry** is according to Deweyan pragmatism and then provides a research overview, which visualizes and explains the two streams of research. Afterwards, the section presents concrete and operational details about the inquiry, which includes a description of the cases (companies and robots), data collection and analysis methods.

Dewey defined **inquiry** as:

> "[...] the controlled or directed transformation of an indeterminate situations into one that is so determinate in its constituents, distinctions and relations as to convert the elements of original situation into a unified whole" (Dewey, 1938 cited in (Goldkuhl, 2012, p. 139)).

Figure 3.1 shows that **inquiry** is required to assess whether **theory**, which is based on prior **experience**, is practical applicable. However, what ignites inquiry is when a **situation** is considered problematic, which calls for further investigation of the situation's constituents (including the **conflicts** and the **qualities**) (Rylander, 2012). Once the situation is better understood, experience and, consequently, theory are revised and refined, which ignites a new circle of inquiry in order to reassess the theory and resolve the problematic situation. The primary goal of inquiry is thus to clarify and provide a richer understanding of a socially situated situation (or phenomena) in order to create knowledge that makes a purposeful difference in practice in a given situation (Goldkuhl, 2012; Stark, 2014; Kaushik & Walsh, 2019).

Undertaking an abductive inquiry does not typically remove the researcher from the object of study. To account for this, Dewey coined the term **transaction** which is defined as:

> "[...] the ongoing and transformative interrelations between the experiencer and his/her circumstances: the flow of experience incessantly influences the experiencer, who in turn transforms with the circumstances in order to pursue certain experiences" (Dalsgaard, 2008, p. 23).

In this case, the 'experiencer' is the researcher. How the researcher reacts and shapes the research is therefore not only guided by theory and empirical results, as "emotions and preferences operate throughout the inquiry process, starting most notably with a *feeling* that something is problematic in a situation" (Morgan, 2014b, p. 1048)[1], and this might trigger a series of thought experiments in order to propose ways of resolving the problematic situation before turning into full-fledged inquires (Dalsgaard, 2008). Inquiry is not coincidental but rather a self-conscious process of decision making (Morgan, 2014a) that moves back and forth between induction and deduction (Morgan, 2007). This is important to keep in mind, because while the choice of method(ologie)s are sound and appropriate for the outlined research and in answering the research questions presented in this dissertation and in the individual papers, there is always an element of feelings, emotion, and preferences guiding those choices which are undeniably socially situated and guided by our individual background.

3.2.1 Research Overview

This section provides an overview of my research as illustrated in Figure 3.2. This illustration shows two streams of research: **development of the RODECA** (Papers 1 and 2) and **understanding how robots are developed** (Papers 3 and 4). The two streams intersect when answering the research questions.

The first stream of research (**development of the RODECA**) began with a pilot project (Paper 1) involving robotics experts from academia and industry as well as UX consultants with robot development experience. RODECA was conceptualized based on inputs from participants in two workshops, feedback gained from two robotics companies applying RODECA (retrospectively) to one of their projects, and literature on HRI design frameworks. Findings from this study offer insights into industry robot designers' requirements for HRI design frameworks (RQ1) and proposes RODECA as a possible solution that may support robotics companies to integrate and adopt UX (RQ3). Practitioners highlighted that the ability to fa-

[1]This proposition is based on William James' contribution to pragmatism, which was adopted by Dewey.

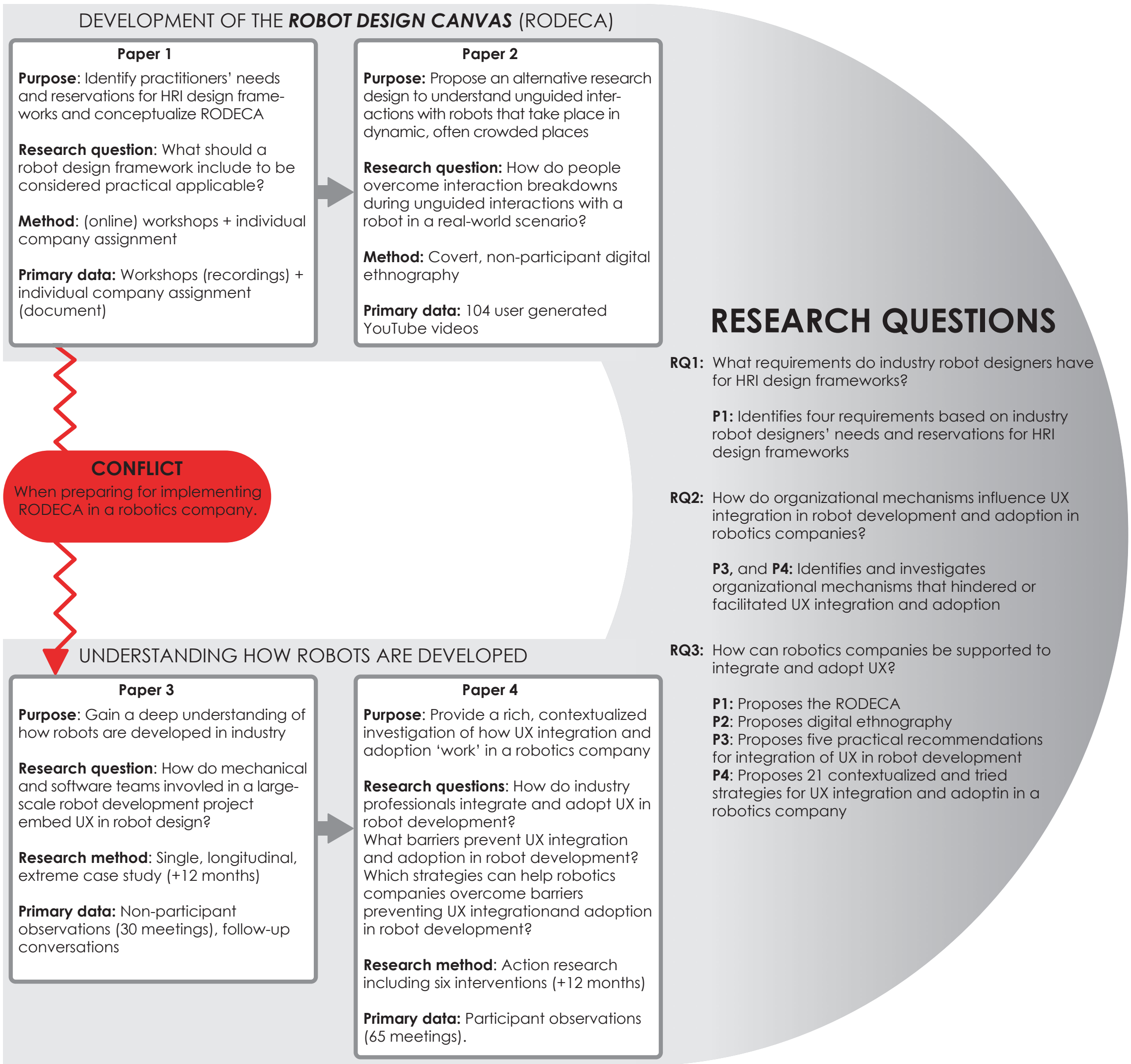

Figure 3.2: Overview of the **purpose**, **research questions**, **methods**, and **primary data** sources for the four papers, divided into the two research streams, and how they connect to the research questions.

cilitate market and application exploration would be highly valuable in a robot design framework. This requirement thus inspired the second inquiry, which was initially conducted in collaboration with one of the UX consultancies in the pilot project. They shared their results from field visits and contextual interviews, and they wanted to explore opportunities and possible value propositions for introducing a social service robot at a hospital, which could provide wayfinding to hospital visitors and alleviate some of the identified issues with current means of wayfinding. I proposed digital ethnography (Paper 2) as a way to explore whether and how a social service robot could offer wayfinding help to hospital visitors. However, the review process required that we omitted details about the collaboration with the company and focused entirely on the methodology, and this is evident in the paper. Even so, utilizing digital ethnography can be considered an extension to traditional competitor analysis which allow practitioners to conduct market and application exploration with a focus on how people interact with robots in various contexts and which contextual factors may influence this interaction. Paper 2 thus offers one way that can support robotics companies in integrating UX insights into robot development (RQ3).

The second stream of research (**understanding how robots are developed**) was pursued as a result of an experienced **conflict** that occurred in the preparation of implementing RODECA in a robotics company that had not been part of the pilot project. The empirical evidence that indicated this potential conflict was the initial semi-structured interview with a product manager and some of the first meeting-observations which were used to make a UX maturity assessment of the case company (detailed in Papers 3 and 4). This assessment indicated that it would not be realistic to implement RODECA or other HRI design framework in this **situation**. The UX maturity assessment can be found in Appendix A. This **conflict** challenged my research plans, as it pointed towards a possible misalignment between what practitioners articulated that they needed (Paper 1) versus what they appeared to need based on empirical evidence gathered in Papers 3 and 4. To resolve this **conflict** inline with the pragmatic spirit necessitated a thorough investigation of the **situation** and the organizational mechanisms that influence integration and adoption of UX (RQ2). This stream of research was accomplished through an extreme and longitudinal case study (Paper 3) and action research collaboration (Paper 4) within a large, well-established company developing social service robots. This stream of research emphasized the criticality of understanding how robots are developed in order to formulate applicable research-based recommendations and strategies that support UX integration and adoption in robotics companies (RQ3).

Throughout abductive inquiry, my understanding (i.e., the **theory**) of the problem changed considerably when I started collaborating with the company involved in Papers 3 and 4. According to Morgan (2014a), this should lead you to reassess the problem and initiate a new cycle of **inquiry**. This process compelled me to divert from the first stream of research concerned with validating RODECA to the second stream of research, which addressed a more important and pressing problem that if solved would have higher practical value to practitioners: How can robotics companies be supported to integrate and adopt UX? (RQ3).

3.2.2 Case Selection

This section explains how and which cases were selected, and provides a brief introduction of the companies I have collaborated with and explains why they are interesting cases. The section additionally provides further details regarding the included robots.

I have collaborated closely with two of the three robotics startup companies, two of the three UX consultancy firms, and one large, well-established company including their many external project partners (which include one of the UX consultancy firms). Each company was

Table 3.2: Case selection. Information regarding Papers 3 and 4 are the same.

	Paper 1	Paper 2	Papers 3 and Paper 4
Case selection strategy	Purposive sampling: maximum variation case (Flyvbjerg, 2006)	Purposive sampling combined with technology-oriented and case-specific keywords	Purposive sampling: extreme, longitudinal case (Yin, 2018; Flyvbjerg, 2006)
Participants	CEOs, CTOs, CXO, project developer, UX designer, engineers, and researchers (HRI, robotics, technology consultant)	UX consultants from UXC1, 99 YouTubers	40+ internal domain experts (incl. project, product, and supply chain management; mechanical, electrical, software, hardware, and test engineers; software architects, systems designers, autonomy developer, UX designer, senior managers) and external partners (incl. two senior UX designers and a digital designer)
Selected cases	*Empirical context* Robotics startup (R1-3), robot integrator (2), AI company (1), UX consultancy (UXC1-2)	*Empirical context* Hospital wayfinding, 104 user generated YouTube videos of unguided interactions with robots in public places	*Empirical context* Robot development team in a large, well-established company (anonymous)
	Robots (3) Hircus, Serena, and TinyLineMarker Sport	*Robots (17)* AirStar (45.2%), Marty (12.5%), Pepper (11.5%), Savioke (7.7%), KnightScope (6.7%)	*Robots (2)* Large and small cleaning robots

selected based on **purposive sampling**, where relevant and information rich sources are selected (Yin, 2016). This strategy is also known as **information-oriented selection** (Flyvbjerg, 2006). That is, each of the case companies had an interest in exploring whether and how UX could be integrated in robot development and adopted in their respective companies. Additionally, the robotics companies were chosen because they were in the early development phase, which increase the possibility of influencing their processes and practices, and, consequently, the UX of the their social service robots. The UX consultants were included because they have experience working with UX of robots although largely confined to the design of the robot's screen-based touch interface. Researchers were included to ensure academic depth, and provide alternative perspectives.

As shown in Table 3.2, multiple cases where selected in Paper 1 in order to capture various perspectives in discussions of requirements and applicability of HRI design frameworks and the conceptualization of RODECA. These case companies were selected because they each saw value in adopting UX in robot development despite having different professional backgrounds and UX expertise and experience. Furthermore, the participants from the case companies ensured informative representativeness, as they represented a broad range of stakeholders (such as CEOs, CTOs, UX designers, and engineers) who would in someway influence the UX integration and adoption process. Consequently, the selected cases resembles **maximum variation** cases, which seeks to obtain rich information from multiple cases that vary on one or more dimensions (Flyvbjerg, 2006). In this study, we involved three robotics startups, two UX consultancy firms, two robot integrators, one AI company, and researchers from three research institutions. Involving three robotics startup companies additionally contributed to product variety, as their robots target different markets, operate in a myriad of contexts, and fulfills several different tasks, as summarized in Table 3.4.

At the outset of the second study (Paper 2), I collaborated with one of the UX consultancy firms (UXC1), who participated in the pilot project. What they contributed with to this study was a **common** case, which seeks "to capture the circumstances and conditions of an everyday situation" (Yin, 2018, p. 98). The everyday situation that they had studied through field visits and contextual interviews focused on how hospital visitors (both patients and relatives) find their way around a hospital. I recognize that to many people visiting a hospital is not an everyday situation, but navigating in large buildings can easily be considered an everyday situation. As mentioned previously, the peer review process had me change direction and focus entirely on the methodological contribution of digital ethnography to study unguided interactions with robots in public places. This consequently called for a **purposive sampling** strategy, which was combined with using technology-oriented and case-specific keywords (Nielsen, Skov, Hansen, & Kaszowska, 2023).

In Papers 3 and 4, a single case was selected, as is appropriate for studying real-world contemporary phenomenons in depth and developing insights into *how* questions (Flyvbjerg, 2006; Yin, 2018). This case is considered **longitudinal** exploring the phenomenon over extended time (+12 months) allowing the researcher to detect changes (Yin, 2018) and **extreme** as it attends to deeper causes and consequences of how multiple teams embed UX in a shared robot development project within a large, well-established company (Nielsen, Skov, & Bruun, 2023). What makes this an extreme case is also that it seeks to obtain in-depth information about **problematic situations** occurring under certain circumstances while activating numerous stakeholders and mechanisms (Flyvbjerg, 2006). Furthermore, an extreme case deviates from theoretical norms (Yin, 2018) by providing new perspectives–in the case of this dissertation–in HRI research, which traditionally deals with UX in terms of evaluating UX or establishing design guidelines (Sandoval et al., 2018; Wallström & Lindblom, 2020; Lindblom & Andreasson, 2016; Lindblom et al., 2020; Zhong & Schmiedel, 2021) or realized by means of HRI design frameworks (Tonkin et al., 2018; Axelsson et al., 2021), and "[...] in HCI research, which traditionally explores UX integration predominantly from the perspective of UX specialists and software developers" (Nielsen, Skov, & Bruun, 2023, p. 44).

Case Companies

This section offers background information[2] about the robotics companies I have worked with most closely: R1 (CapraRobotics), R2 (Coalescent Mobile Robots), and R4 (anonymous). The two startup companies contributed to the conceptualization of RODECA, which included completing the individual company assignment, where they applied RODECA retrospectively to their robot development. The large, well-established company is the company with whom I collaborated with for more than a year on integrating and adopting UX. Factual background information about the three companies are presented in Table 3.3.

The robot development taking place in R1 is considered technology-centered, because they developed a versatile robot platform driven by what was technological possible *before* having identified a problem to be solved or a user need to be fulfilled. Having this versatile robot platform allows the company to enter various markets and develop highly customized robots for specific customers and contexts. In this company, UX is considered valuable primarily in the final phases of development, where nearly finished robots are evaluated by authentic users or proxies ideally in the real context, but this is not a must. Additionally, UX is limited to the surface level attending, for example, to the colors of the robot. Finally, the company hires external UX designers or UX interns to collaborate with other domain experts.

The robot development taking place in R2 is, conversely, considered human-centered because the company invested resources in upfront design activities from where they specified user requirements, which influenced decisions regarding the robot design, and, lastly, they frequently evaluated their prototypes in-situ with authentic users *during* development. However, the company recognizes that they are constrained by what is technological possible. In this robotics company, UX is embedded throughout the entire development process, in so far

[2]The information provided in this section is based on data from a survey collecting factual background information about the company and a semi-structured interview with one representative (CEO, CXO, and product manager) from each company. The survey was administered a few days before the interview. The interview focused on: robot application; outlining design and development processes; knowledge transfer, workflows and collaboration; and integration of UX practices. Interviews were recorded upon written and verbal consent and lasted approximately two hours each.

Table 3.3: Background information of the three robotics companies who have contributed most to my research. Information is based on data from a survey, administrated prior to the semi-structured interview, which focused on factual background information. **Mission** and **Vision** are related specifically to their robots.

	R1 (Paper 1)	R2 (Paper 1)	R4 (Papers 3 and 4)
Company	CapraRobotics	Coalescent Mobile Robots	Large, well-established company (anonymous)
Size	10-50 employees	10-50 employees	4500+ employees
Placement	Co-located	Co-located	Distributed
Mission	To create robots that are simple and robust, easy to use, and fair priced	To enable people and robots to collaborate and work together in order to make our lives easier	Do not have one
Vision	To create mobile robots that help people everywhere	Creating robots for retail that are innovative but accessible. We want our customers to be progressive and not afraid of change	Do not have one

that market research, business strategy, and customer insights and requirements agree that a robotic installment will solve identified issues and needs. The company is not limited exclusively to issues and needs identified in market research, business strategy, or by customers as they are allowed to revise the issues and needs according to insights from UX activities. Insights from UX activities additionally influence how the robot's attributes are designed. Thus, in R2, UX is not only a matter of evaluating a finished robot nor limited to a screen-based touch interface, it imbues the entire development of the robot. Moreover, they have their own internal UX designer and researcher to plan, execute, analyze, communicate, and ensure quality in UX activities.

Lastly, the robot development taking place in R4 foregrounded technology and customer demands. This specific robot development project was commissioned by a high-paying customer who–together with product managers and senior managers–defined the requirements, which focused on operational efficiency and technical specifications. Development decisions were thus chiefly based on what was technological feasible given the constraints of requirements, time, and budget. The product manager established user requirements based on the customer requirements and technical specifications, but these were not vetted by authentic users. Design decisions were therefore chiefly made by internal stakeholders sometimes based on recommendations provided by external UX consultants[3]. The company considered

[3]The external UX consultants were tasked with UI design based on pre-defined requirements and thus not paid to carry out other UX activities, such as user tests (Nielsen, Skov, & Bruun, 2023)

this robot development project a *breakthrough project*, as this was the first time they combined several technical teams (an explicitly software team, a mechanical team, a hardware team, an electrical team, an autonomy team, test engineers, and systems engineers to mention some of the technical disciplines involved) in a robot development project (Nielsen, Skov, & Bruun, 2023). Additionally, at least one senior manager saw this as an opportunity to integrate UX in robot development and recognized the need for outside help to facilitate the process (Nielsen, Ordoñez, et al., 2023); and this is where my research and RODECA came in. However, R4 does have an internal UX designer–whose main responsibilities relate to the company's digital product portfolio–who decided to join the robot development project out of professional and personal interest (Nielsen, Ordoñez, et al., 2023; Nielsen, Skov, & Bruun, 2023).

This dissertation is concerned with robotics companies who see the value of UX–regardless of what that value might be–but who struggle to integrate UX in robot development and adopt UX in the organization. Of particular interest are robotics companies with in-house design and development of their own social service robots designed to operate in a variety of contexts. The dissertation does not focus on robotics companies who purchase and customize existing commercial robots, such as Pepper and NAO.

Robots

As mentioned in Section 1.2, service robots fall into two categories: **professional** service robots, which assist people (referred to as *operators* or using their professional job title, e.g., *facility staff* which includes both cleaning personnel and their supervisors) in achieving professional goals, and **personal** service robots, which assist or entertain people (referred to as InCoPs) in domestic settings or during recreational activities (Thrun, 2004). In this dissertation, I argue that these service robots have a social layer, which is why I refer to them as **social service robots**. A total of 22 different social service robots have been included in my research. Figure 3.3 shows the three robots that the robotics startup companies have developed and Figure 3.4 shows four out of the 17 robots analyzed in Paper 2[4]. A signed non-disclosure agreement prevent me from showing the large, well-established company's robots, as this would disclose the company name and ease the identification of certain practitioners.

Table 3.4 summarizes the **purpose** of the robots, the **contexts** in which they operate, the **tasks** they are designed to complete, and who the robot's **primary user(s)** are considered to be. As demonstrated in Table 3.4, I have considered a wide range of social service robots who served different purposes (e.g., customer service, security, cleaning, transportation, line marking), operated in a variety of contexts (primarily large indoor facilities, with two robots specifically designed to operate outdoors), and fulfilled various tasks (wayfinding, entertainment,

[4]While the cleaning robot (T7AMR) only shows up in one YouTube video, I am including it in the figure as a reference to the two cleaning robots developed by the large, well-established company, who wish to remain anonymous.

Figure 3.3: From Paper 1: Capra Robotics' Hircus, Coalescent Mobile Robotics' Serena (lab demo), and TinyMobileRobots' TinyLineMarker Sport. *Disclosure is accepted.*

Figure 3.4: Examples of robots studied in Paper 2. From left to right: AirStar, KnightScope, Marty, and T7AMR.

information kiosk, room service, cleaning, logistics, etc.) to different primary users (e.g., facility staff, service technicians[5], and InCoPs). However, only one of the robots–Hircus–can truly be considered a multipurpose robot, as it has a flexible platform design that allows for it to be customized and support various purposes, contexts, tasks, and primary users. The other robots may also support different tasks, but typically within the same overall category, e.g., customer service, cleaning, logistics, and delivery of items, and with limited possibilities of changing the physical properties of the robot.

This dissertation is concerned with the design of social service robots which operate in a variety of contexts fulfilling various tasks for facility staff, service technicians, and InCoPs who decide to utilize and interact with the robot, while also considering other people in the environment. Specifically, the dissertation focuses on how professionals from robotics companies design the robot platform, the way the robot communicates with primary and non-primary users and interacts with its surroundings, as well as the robot's interface(s).

[5]While facility staff are tasked with operating the robots, the service technician are responsible for providing service, maintenance, and repair the robots. Service technicians are trained and employed by R4.

Table 3.4: Details of purpose, contexts, tasks, and primary user(s) of the robots considered in my research. For R1 the information about the robot (Hircus) is only examples of its purposes, contexts of operation, tasks, and primary users.

	Paper 1	Paper 2	Papers 3 and 4
Purpose	Inspection, logistics, and maintenance (R1), in-store transportation (R2), line marking (R3)	Customer service, security, delivery, advertising, and cleaning	Support facility staff in cleaning tasks
Contexts	Outdoor and indoor facilities (R1), retail stores (R2), sports pitches (R3)	Airport (56.7%), grocery store (16.4%), shopping mall (13.5%), hotel (9.6%), restaurant (1%), hospital (1%), train station (1%), museum (1%)	Large indoor facilities such as airports, hotels, and grocery stores
Tasks	Detecting breaches in fences, picking up cigarette butts, transporting goods (R1), transporting goods for restocking and Click & Collect (R2), line marking pitches (R3)	Wayfinding, entertainment, information kiosk, room service, advertising, surveillance, cleaning, and detecting spills and debris	Autonomous and manual cleaning
Primary user(s)	Facility staff (R1), store personnel (R2), facility staff (e.g., grounds manager) (R3)	InCoPs who decide to interact with the robot(s)	Facility staff (i.e., cleaning personnel and supervisors) and service technicians

3.2.3 Data Collection

A variety of data collection methods have been applied throughout the Ph.D. project. Table 3.5 summarizes the different types of data collected in each of the four papers. This section provides additional factual information about the data, before accounting for the choice of real-time and retrospective data collection methods.

Table 3.5: Overview of collected data and whether data were collected real-time or retrospectively as well as whether data are considered primary or secondary data.

	Paper 1	Paper 2	Paper 3	Paper 4
Type of data	Real-time and retrospective data	Real-time data	Real-time and retrospective data	Real-time and retrospective data
Primary data	Workshops (2), individual company assignment (2)	Covert, non-participant observations (104 YouTube videos)	Overt, non-participant observations (30 meetings), follow-up conversations	Overt, participant observations (65 meetings)
Secondary data	-	-	Slides, emails, documents, access to Jira	Semi-structured interview (1), practitioner diary (11), researcher's journal

Factual Information about Data

The primary data in Paper 1 comprised of two recorded online workshops, which lasted about 1 hour each (≈ 2 hours in total). In workshop 1, three questions were discussed in plenum with industry professionals and academic researchers: *1) What would it take for RODECA to be valuable and useful for your organization?*; *2) What are your main concerns about such a canvas? and how might we address these?*; and *3) What kind of expertise would be needed for a project at your company to follow the design process?* (Nielsen, Ordoñez, Hansen, Skov, & Jochum, 2021). Workshop 2 focused on four challenges identified in practitioners' responses to the individual company assignment: Forming a common language, the applicability of robot attributes, using the business model canvas, and identifying success criteria (Nielsen et al., 2021). Additionally, data comprised an individual company assignment where practitioners from two robotics companies applied RODECA retrospectively to one of their robot development projects. The assignment was administered in a written format, which practitioners completed in writing[6].

The primary data collected in Paper 2 was 104 YouTube videos uploaded by 99 unique YouTubers depicting unguided interactions with social service robots in various public places. The data collection took place between March 31st and April 7th 2020, and used a combination of technology-oriented (type of robots, e.g. *wayfinding robot*) and case-specific keywords (public places where robots have been deployed, e.g., *airport*). The search phase yielded an initial set

[6]Practitioners provided answers to the questions included in RODECA as presented in Nielsen et al. (2021).

of 560 videos, which were subjected to a three step filtering process arriving at a sample of 104 videos. The paper provides extensive details about the data collection procedures, meta-information about the videos, and of the content of the videos, including information about the people interacting with the robots (Nielsen, Skov, Hansen, & Kaszowska, 2023). As mentioned in the paper, the average length of the analyzed segments depicting robot encounters and interactions in Paper 2 were 2.13 minutes (STD = 2.19) with the shortest segment being 9 seconds and the longest 14.43 minutes (Nielsen, Skov, Hansen, & Kaszowska, 2023). A total of 194 minutes ($\approx$ 3 hours and 15 minutes) were analyzed.

Primary data for the case study (Paper 3) comprised of overt, non-participants observations of 30 project scrum meetings which took place between May and October 2021. The scrum meetings lasted on average 28 minutes (STD = 8.1), with the shortest being 8 minutes and the longest being 60 minutes. A total of $\approx$ 14 hours were analyzed. Follow-up conversations were conducted immediately after the scrum meeting, if needed, and typically lasted no more than 15 minutes (this is included in the $\approx$ 14 hours being analyzed).

The overt, participant observations in Paper 4 were based on 65 sessions which took place between May 2021 and April 2022[7] and lasted on average 59.3 minutes (STD = 29.4), with the shortest lasting 15 minutes and the longest lasting 150 minutes. In total, 62 hours and 15 minutes were analyzed. Practitioners' diary was based on a responsive survey design, where previous answers led to certain subsequent questions. The survey comprised of 90 questions, which practitioners answered after each of the six interventions in the action research collaboration. A template version of the survey can accessed here. For intervention 1 to 5, two practitioners' completed the survey, whereas for intervention 6 only one practitioner completed the survey. The researcher's journal comprised of handwritten notes taken during each of the six interventions of the action research covering the entire 12+ months collaboration.

Additional secondary data such as access to the development team's project management tool Jira, emails, documents, and presentation slides are not easily or meaningfully quantifiable. Even so, some documents were produced as part of the action research collaboration, which included, for example, company templates to document user studies as well as excel documents containing the IDA-GA analysis[8]. These documents were however not considered in the analysis, but rather seen as outputs of the action research collaboration. Other documents were produced by practitioners and only shown in meetings through screen sharing (applies to both the case study and action research). Relevant presentation slides for the case study comprised of two concepts design reviews (one lasting 1 hour and 30 minutes and one

[7]The contract negotiations began in January 2021.

[8]IDA stands for *Instant Data Analysis* which is a cost-effective approach to conducting, analyzing, and documenting usability evaluations in a day (Kjeldskov, Skov, & Stage, 2004). In Gap Analysis (GA) "[...] current performance is compared to desired and expected performance" (Nielsen, Ordoñez, et al., 2023, p. 13).

lasting 3 hours) and one prototype design review (lasting 2 hours) [9]. The presentation slides of particular interest to the action research were slides the UX designer and I developed to report findings from one of the user studies to product managers, as well as other documentation needed for carrying out the six different user studies (e.g., moderator training material). Again, the specific document were not considered in the analysis, but the process of creating it was captured in observations notes and thus included in the analysis.

The semi-structured interview with the product manager from the large, well-established company lasted 1 hour and 45 minutes, which were followed by a 2 hour onboarding session facilitated by the product manager. This is the only semi-structured interview where data have been included in a publication. The remaining two interviews were conducted with a CEO and CXO of the two robotics startup companies, and lasted 2 hours and 5 minutes and 1 hour and 57 minutes respectively, but these have only been used for providing background information about the case companies previously in this chapter. As mentioned in Paper 4, the UX maturity assessment was based on data from the semi-structured interview and a few of the initial observations. It was then shared with the internal Design team members for their individual feedback, before having a group session to discuss the assessment. The group session was recorded and lasted 59 minutes.

Real-Time and Retrospective Data

The data collected for this dissertation was a combination of real-time and retrospective qualitative data, as indicated in Table 3.5. This section mainly focuses on the primary data, particularly the different ways observations were made (covert versus overt and participant versus non-participant), and the decision to collect data in real-time or retrospectively.

Real-time data refers to observations (both participant and non-participant), simultaneous verbalization (e.g., thinking aloud), diary or journal keeping, and recording of documents through snapshots (Blessing & Chakrabarti, 2009). Real-time data is typically collected in real-time and captures how people react to events. Contrarily, retrospective data relies on retrospective accounts of events thereby relying largely on memory. **Retrospective data** includes documents and product data created prior to the data collection, as well as questionnaires, interviews, and focus groups (Blessing & Chakrabarti, 2009), which capture the person or persons explanation of a given topic or phenomenon, and is inherently based on the person's recollection of events (Yin, 2016).

Paper 1 is the only study in this dissertation, which does not rely on observational data. Instead, the primary data comprised of real-time data captured during two online workshops, where we discussed practitioners' needs and reservations regarding HRI design frameworks as

[9] The concept and prototype design reviews are explained in more detail in Paper 3 in Section 4.4 Coordination Through Ceremonies and Artifacts (Nielsen, Skov, & Bruun, 2023).

well as other issues mentioned in the beginning of this section and in the paper (Nielsen et al., 2021). Practitioners relied on their expertise and experience with developing robots, and gave examples of what had or had not worked in the past, thus contributing some retrospective accounts. However, the retrospective data deliberately collected in this study were based on practitioners' response to the individual company assignment that asked them to apply RODECA retrospectively to a one of their robot development projects.

The empirical data considered in this dissertation were chiefly based on observations. I have conducted both **covert** (i.e., the people being observed were unaware of that they were being observed (Jacobs, Elprama, & Jewell, 2020)) and **overt** (i.e., the people being observed were aware of that they were being observed (Jacobs et al., 2020)) observations and I have taken on the role as both a non-participant and participant observer. Being a **non-participant observer** typically refers to cases where the researcher is not in direct contact with the people being observed, but rather observes from a distance (Jacobs et al., 2020). This was indeed the case in Paper 2, where the people being observed (i.e., the people recorded in the YouTube videos) were unaware of the fact that their interactions would later be analyzed by a research team. However, non-participant observer was also used to describe the level of participation in the case study (Paper 3), as I did not have an active nor influencing role in practitioners' work, but rather attended meetings passively to observe. In contrast to Paper 2, practitioners in the case study were aware of my presence and that I was observing them. Conversely, **participant observations** reflects situations where the researcher actively engages with participants and participates in the events being studied (Emerson, Fretz, & Shaw, 2011).

The decision regarding *where* to observe–observations in the case study and action research were conducted online–reflected the way the large, well-established company worked as a result of being distributed across several offices and countries. Also, most of my empirical work took place at a time where COVID-19 restrictions were a reality.

Observations were captured in real-time, i.e., as the interaction between InCoPs and robots occurred (Paper 2) and as the actual development of the robot–as well as the integration and adoption of UX–happened (Papers 3 and 4). The reason why I consider the observations of unguided interactions to be real-time is that the observations of what InCoPs did were based on real-time recordings of events; InCoPs recorded their own or others' unguided interactions with robots as they happened real-time. In this particular case, digital ethnography–when based on video recordings–enabled us to revisit these events, despite not having been there in-person when they happened. This and related issues (i.e., ethical considerations) regarding data collection in digital ethnography are discussed at length in the paper (Nielsen, Skov, Hansen, & Kaszowska, 2023).

For the case study, it was important to capture as many perspectives as possible in real-time given the restriction that I could not be in multiple places at once. I therefore concentrated on the shared project scrum meetings rather than making isolated observations of individuals or individual teams. Observations were chosen over interviews as the primary source of data in the case study because we wanted to understand the **situation** and practitioners' actions, which can be tricky to articulate, as they are often tacit. For the case study, I collected overt (i.e., practitioners knew that I was there to observe them and they were informed about what I was observing), non-participant observations (i.e., I did not take an active part in nor influenced what happened), which enabled me to collect a rich, contextualized understanding of how robots were developed and how organizational mechanisms influenced UX integration in robot development and adoption in this organization (RQ2).

Real-time, overt, participant observations were the appropriate and sensitive choice for the action research collaboration. This is because action research is predicated on a close situated collaboration between the researcher and practitioners where there is mutual shaping of and reliance on each others' skills, experiences, and competencies (McKay & Marshall, 2001). From a pragmatic perspective, an important aspect to consider regarding action research is *collective reflection* which entails a linking between reflection and action as well as the consequences of actions which ultimately results in growth (Stark, 2014). This was accomplished through retrospective accounts at the practitioner level (i.e., the diaries that were completed at the end of each intervention) and at the collective level between the researcher and practitioners, who meet to discuss and talk about the experiences of being part of the action research project. Additionally, real-time reflections were made at the researcher level (i.e., the journal capturing my experiences, beliefs, interpretations etc.).

3.2.4 Data Analysis

The real-time and retrospective qualitative data collected for this dissertation were analyzed using a variety of analysis methods, which is an appropriate, pragmatic strategy (Feilzer, 2010; Morgan, 2007). Specifically, a **rapid thematic analysis** was applied in Paper 1, **deductive** and **inductive qualitative content analysis** was applied in Paper 2, **Riceoeur-thinking** was chosen for Paper 3, and **reflexive thematic analysis** was followed in Paper 4. Table 3.6 summarizes the ways data were analyzed. The chosen data analysis procedures share common features regarding preparation, data familiarization, coding procedure, consistency checks, theme generation[10], and reporting of findings while also entailing distinct intra-phase features. This section unfolds the analyses in more detail.

Figure 3.5 visualizes six phases that the data analyses followed. While it may appear as if the analyses followed a linear process, this was not–and it rarely is for qualitative research

[10]**Theme** is used in thematic analysis (Braun & Clarke, 2022), where as **category** is used in content analysis (Hsieh & Shannon, 2005). However, they refer to the same thing (Vaismoradi, Turunen, & Bondas, 2013); a clustering of codes that "captures shared meaning, united by a central organising concept" (Braun & Clarke, 2022, p. 77). For simplicity, I use the term '**theme**' in this dissertation.

Table 3.6: Overview of data analysis procedures.

	Paper 1	Paper 2	Paper 3	Paper 4
Method	Rapid thematic analysis	Qualitative content analysis (Cho & Lee, 2014; Hsieh & Shannon, 2005)	Riceour-inspired analysis (Simonÿ et al., 2018)	Reflexive thematic analysis (Braun & Clarke, 2022)
Type of codes	Semantic	Semantic	Semantic and latent	Semantic and latent
Orientation	Inductive	Deductive and inductive	Inductive	Inductive
Consistency checks	Co-author discussions, member check focus groups (Birt, Scott, Cavers, Campbell, & Walter, 2016)	Co-author discussions, intercoder reliability	Co-author discussions, member check interview (Birt et al., 2016)	Co-author discussions, member check using synthesized analyzed data and interview (Birt et al., 2016), intercoder reliability

(Vaismoradi et al., 2013; Braun & Clarke, 2022)–the case. The preparation of data happened only once, but already in this phase, the familiarization began. Reading and revisiting the data transcripts and raw data files were thus not only part of the familiarization phase, but happened throughout the open coding, generation of themes, and reporting of findings to ensure that the codes and themes accurately fitted and reflected the data. Identifying, defining, and assigning codes as well as generating themes were similarly an intertwined and concurrent activity, with regular consistency checks.

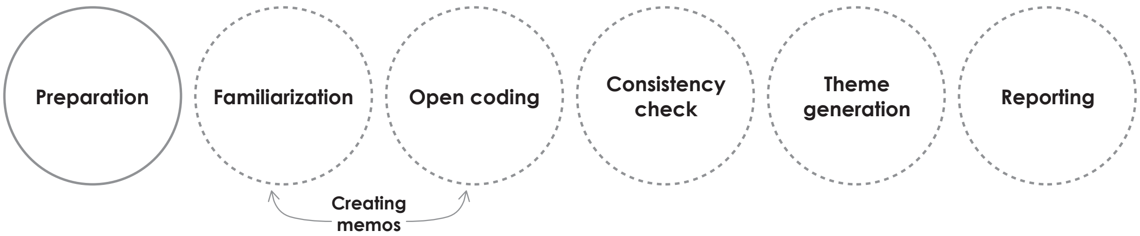

Figure 3.5: Overview of data analysis procedures. Solid circle implies that the activity happened once, whereas dotted circles imply both inter and intra phase iterations.

Preparation

All data were prepared as the first step in any of the data analyses. This included downloading and otherwise saving (e.g., YouTube videos were saved in a private playlist on YouTube) the relevant files; transcribing workshop recordings, interviews, and YouTube videos; and reformatting and anonymizing observational notes.

Familiarization

After the data preparation phase, the analyses continued with data familiarization in all four studies. In the familiarization phase, the goal is to familiarize oneself deeply with data through **immersion** (thoroughly reading and re-reading data transcripts, files, and video recordings) and **critical engagement** (being active, critical, and analytical in order to make sense, contest and challenge, critique and imagine how things could be different) (Braun & Clarke, 2022). This meant that I revisited and read (or watched) all of the data more than once. For Papers 3 and 4, the familiarization phase also included consolidating the primary data with secondary data, particularly practitioners' diaries and my research journal, and, later, the remaining secondary data were considered.

What guided the processes of immersion and critical engagement in Papers 2-4 were note-taking (Braun & Clarke, 2022), where I created memos and visuals depicting thoughts and ideas about how the data concepts might connect to one another.

Open Coding

Regardless of which analysis method that was applied, the data were coded in an **open coding** fashion, which implies that the coding processes were dynamic and evolving. Best practices were followed regarding the codes which must be mutually exclusive and capture single meanings or concepts (Braun & Clarke, 2022). Furthermore, transcripts were primarily coded **line-by-line**, whereas paragraph-by-paragraph coding were used if relevant. Word-by-word coding were rarely used. Memos were additionally captured as part of the open coding phase, as recommended by both Hsieh and Shannon (2005) and Braun and Clarke (2022).

The coding processes applied a combination of semantic and latent codes. **Semantic codes** capture explicitly-expressed meanings that stay close the participants' language and articulation (such codes are also referred to as **in-vivo** codes (Glaser & Strauss, 1967) or as **manifest** codes in content analysis (Cho & Lee, 2014)), whereas **latent codes** are often researcher-driven and capture deeper and more implicit meanings (such codes are also referred to as **constructive** codes) (Braun & Clarke, 2022). The rapid thematic analysis (Paper 1) and content analysis (Paper 2) were primarily coded at the semantic level. Contrarily, the reflexive thematic analysis (Paper 4) and the Riceour-inspired analysis (Paper 3) considered both semantic and latent codes. The content analysis was conducted deductively and inductively, which meant that some codes were derived from literature, while a majority of codes were generated based on the data itself. An inductive orientation was similarly adopted in the reflexive thematic analysis, the Riceour-inspired analysis, and the rapid thematic analysis. When adopting an **inductive orientation**, codes *evolve* through the coding process, and this means that codes can be sharpened or expanded. Allowing codes to evolve in this way reduce the risk that codes lack nuance, subtlety, or depth and ensure a more nuanced coding and "that richer analytic insights are systematically captured" (Braun & Clarke, 2022, p. 55). In this part of the coding process, the researcher is encouraged to identify patterns of meaning by capturing closely-related ideas or meanings within a single code (Braun & Clarke, 2022). Although the Riceour-inspired analysis considered both semantic and latent codes, the coding process slightly differed from the remaining three analyses. As explained in Paper 3, during the data familiarization phase the first author (i.e., me) "gain[ed] overview of relevant units of meaning (i.e., what is said and observed)" (Nielsen, Skov, & Bruun, 2023, p. 46), which informed the selected codes. Furthermore, a formal coding process is typically not required in rapid approaches to qualitative analysis, which rely much more on summarizing data in order to quickly identify the main practical issues (Taylor, Henshall, Kenyon, Litchfield, & Greenfield, 2018). Consequently, the coding process in Paper 1 does not match the level of detail and engagement with data as in the remaining three papers.

Once the initial round of open coding was performed, I carefully read through all of the data that was coded using each of the codes to ensure that the coded data represented a single meaning or concept and considered whether a code was too broad or too narrow. Likewise, I considered whether codes overlapped with other codes without them being easily distinguishable (they could address the same issue but had to provide different perspectives). Consequently, I revisited the data several times in order to revise and refine the coding schemes. Refining the codes by revisiting the data is considered good practice as it ensures rigour (Braun & Clarke, 2022). Whenever a new code or theme were generated all data files were revisited and coded according to the change.

Consistency Checks

Consistency checks were performed in each study and included peer debriefing sessions (Papers 1-4), deployment of different member check techniques (Papers 1, 3, and 4), and statistical computations of intercoder reliability scores (Papers 2 and 4). Together, these consistency checks enhanced the trustworthiness and quality of research findings[11].

Peer debriefing I frequently meet with co-authors during each of the analyses to discuss the codes and themes. These sessions contributed to the refinement of coherent codes and themes

[11] These consistency checks reflect some of the techniques I applied to establish trustworthiness and quality in research, which is discussed more thoroughly in Section 3.4.

by ensuring that they were mutually exclusive and that codes captured a shared meaning or concept while themes were united by a central organizing concept.

Member check techniques Member checks are a well-acknowledged technique to establish trustworthiness and raise credibility of research findings. Birt et al. (2016) provide a thorough account of different member check techniques, which are relevant for qualitative research. Specifically, **member check focus groups** (Birt et al., 2016) were used in Paper 1 where we arranged the second workshop to follow up and discuss findings from the individual company assignments, rather than providing each of the workshop participants with a draft of our analysis. Contrarily, **member check using synthesized analyzed data** (Birt et al., 2016)–where participants are provided the opportunity to comment on the analysis and add information if need–were used to asses the correctness and credibility of the UX maturity assessment included in Paper 4. In Papers 3 and 4, we additionally used what is referred to as **member check interview** (Birt et al., 2016), despite not relying on interviews for our primary data. Deploying this technique was essential to ensure that when utilizing participant quotes in the paper manuscripts, the participants had the opportunity to confirm, modify, and verify the quotes and the particular use of them prior to publication.

Intercoder reliability Computing an intercoder reliability score is a well-established and well-regarded measure of reliability and reproducability in quantitative research (O'Connor & Joffe, 2020). However, whether or not this seemingly positivistic measure of reliability and reproducability is suitable for qualitative research is an on-going debate (Braun & Clarke, 2022; Guest, MacQueen, & Namey, 2014; McHugh, 2012; O'Connor & Joffe, 2020; Vaismoradi et al., 2013; Nowell, Norris, White, & Moules, 2017), which we discuss in (Nielsen, Ordoñez, et al., 2023). One of the core concerns of introducing intercoder reliability checks in qualitative research is that it conflicts with the underlying proposition that knowledge is inherently situated, and that the reflexive nature of the analysis implies that the analysis itself is shaped by the practices and processes of the actors involved, which is not something that should be controlled for (Braun & Clarke, 2022).

Even though intercoder reliability is often associated with positivist approaches, its use in this pragmatic dissertation serves a different purpose. In Papers 2 and 4, I employed intercoder reliability checks not as a pursuit of an objective truth, but as a tool to enhance the credibility and dependability (the qualitative counterparts to internal validity and reliability, respectively (Guba, 1981)) of our interpretations. This aligns with the pragmatic focus on 'what works' to produce reliable, actionable knowledge.

In the context of my research, intercoder reliability served multiple pragmatic functions:

1. It provided a structured way to discuss and refine our understanding of the data, lead-

ing to richer, more nuanced interpretations.

2. It enhanced the transparency of our analytical process, making our findings more trustworthy and usable for practitioners.

3. It served as a form of investigator triangulation, aligning with the pragmatic emphasis on multiple perspectives.

This use of intercoder reliability checks exemplifies how pragmatism allows for methodological pluralism, drawing on diverse tools to enhance the quality and usefulness of research outcomes. As Morgan (2007) argues, pragmatism rejects the need for a forced choice between different methodological approaches, instead focusing on their complementary strengths.

Theme Generation

In reflexive thematic analysis, a **theme** "[...] captures shared meaning, united by a central organising concept" (Braun & Clarke, 2022, p. 77). Contrarily, the data reduction orientation in content analysis often results in themes (which in content analysis are called **categories** (Hsieh & Shannon, 2005; Vaismoradi et al., 2013)) that summaries data and reports the frequency of codes (Joffe & Yardley, 2004; Vaismoradi et al., 2013). The difference between a theme (in reflexive thematic analysis) and a topic summary–akin to themes developed in the content analysis and the rapid thematic analysis–is that a theme units around a shared meaning or idea, whereas the topic summary units around a topic that summarizes everything the participants say or do related to that specific topic (Braun & Clarke, 2022). It is argued that themes in reflexive thematic analysis encompasses both latent and semantic meaning, while themes in content analysis typically reflects semantic content (Joffe & Yardley, 2004). Depending on the orientation one adopts in the analysis, candidate themes are typically decided prior to the open coding phase commences when adopting a deductive orientation, whereas the opposite is true for an inductive orientation; themes are generated from the codes.

Theme generation happened concurrently with the open coding phase in all four studies, where themes were discussed extensively with co-authors to ensure that themes were coherent and united by a central organizing concept. **Candidate themes** were identified either deductively or inductively and further developed and refined *while* data were being coded and when reporting findings. Furthermore, various thematic maps visualizing how codes and themes related to each other were created on paper and in the software (NVivo) used for conducting the reflexive thematic analysis.

Specifically for the reflexive thematic analysis reported in Paper 4, the theme generation followed the three phases put forward by Braun and Clarke (Braun & Clarke, 2022): generating initial candidate themes, developing and reviewing themes, and refining, defining, and naming themes. Similarly, in the Riceour-inspired analysis reported in Paper 3, themes evolved through the first (which included identifying relevant units of meaning, i.e., what is said and observed) and second (encompasses a structural analysis which alternated between units of meaning and units of significance, which represented what practitioners talked about and what the observations were about) phases of the analysis, and were further refined in the third phase, where "we critically interpreted and discussed themes in relation to existing research" (Nielsen, Skov, & Bruun, 2023, p. 46). In comparison, the themes generated in the pilot project, reported in Paper 1, were arrived at much faster.

The themes generated in Paper 1 provide insights into industry robot designers' requirements for HRI design frameworks (RQ1), whereas the themes generated in Papers 3 and 4 provide insights into how organizational mechanisms influence UX integration in robot development and adoption of UX in robotics companies (RQ2) and how robotics companies can be supported to integrate and adopt UX (RQ3). In the context of this dissertation, Paper 2 is considered a methodological contribution, which can support practitioners' decision-making and incorporation of UX insights in robot development.

Reporting

The reporting of findings followed best practices of reflexive thematic analysis, even in the analyses that did not deploy this analysis method. In reflexive thematic analysis, it is considered good practice to write the paper manuscript concurrently with the analysis itself, as these are embedded processes (Braun & Clarke, 2022). The outcome of this phase are the four papers themselves.

One distinction that have been made in the reporting of my research is the use of **thick descriptions**, which is originally an ethnographic term (Geertz, 1973). Thick descriptions enable readers to clearly and vividly create an image as close as possible to the raw experience the researcher had (Emerson et al., 2011). As Paper 2 reports a digital ethnographic study, this is the only paper were thick descriptions–in an ethnographic sense–were used to report our findings. Contrarily, the other papers rely more heavily on participant quotes. However, **thick descriptions** can also refer to clear and detailed accounts of the social context(s) wherein data was collected, which ultimately provides a rich account of the phenomenon being studied; the context which the analyzed data represents (Shah & Corley, 2006). This was how thick descriptions were considered in Papers 3 and 4.

3.3 Researcher's Position

Section 3.2.3 considered the covert and overt as well as non-participant and participant nature of my research. This section further accounts for my role as a pragmatic researcher.

Pragmatism tackles the debate about whether research is inherently objective or subjective, claiming that neither true objectivity nor subjectivity are realistic to accomplish. Instead, pragmatism offer an intersubjective approach that balances the objective and subjective aspects of research as well as the views of participants and those of the research community. Pragmatists consequently move between various frames of references (Morgan, 2007), which is what makes pragmatism a reflexive orientation. Additionally, the action-oriented nature of pragmatism "[...] makes it impossible for an outsider to understand practices by simply 'observing' them; it requires experience with the cultural context from which they emerge" (Eklund, Aguiar, & Amacker, 2021, p. 8). This is comparable to classic ethnographic research, which rest on the researcher becoming part of the community which they study. This is often a slow process, where the researcher, at the beginning, is an outsider who gradually becomes an insider through experience, adaptation, and co-existence (Jacobs et al., 2020). It is this practice of immersion that enables a researcher to grasp what people find meaningful and important with respect to the activities they are involved in, as well as how they experience and respond to events, constraints, and pressure (Emerson et al., 2011). Active participation and immersion implied that I experienced these effects first-hand, which raised my sensitivity and allowed for a deeper, more nuanced understanding of the **situation**.

Engaging in the process depicted in Figure 3.1 required openness and willingness to revisit and revise **theory** such that it was practical applicable, while at the same time respecting and preserving the integrity and needs of the people whose processes and practices I sought to transform. In order to accomplish this, required that I experienced both the **situation** in which the current practices took place (Eklund et al., 2021) and the effects of the suggested and implemented changes (Goldkuhl, 2012). In doing so, I relied on my contextual sensitivity and ability to empathize with the people. Furthermore, it was important that my role–from a company perspective–was to orchestrate and facilitate UX integration and adoption, as well as to support UX competence development of robot designers new to UX as to increase the potential of lasting impact, rather than overtaking practitioners' responsibilities. It was crucial that practitioners themselves were involved and became active partners in the transformation, as recommended by Seidelin et al. (2020), towards a more UX-focused robot design process in order to generate lasting impact and avoid practitioners becoming passive recipients of UX information, as was found by Zaina et al. (2021).

3.4 Trustworthiness of the Research

Concepts such as reliability and validity are rejected by pragmatists because those concepts are derived from a conventionalist's view of knowledge, where absolute 'truth' is considered the end goal (Rylander, 2012). The research presented in this dissertation is therefore assessed based on quality criteria more befitting from a pragmatic standpoint and for assessing qualitative empirical research. According to Hayes (2011) and Shah and Corley (2006), this kind of research is best assessed based on **trustworthiness**, as coined by Lincoln and Guba's (1985) seminal work on naturalistic inquiry, rather than on conventionalist criteria of internal validity, external validity, reliability, and objectivity. Trustworthiness is assessed according to the four naturalistic counterparts to the aforementioned quality criteria, namely: **credibility**, **transferability**, **dependability**, and **confirmability** (Lincoln & Guba, 1985). Table 3.7 summarizes the recommended techniques and the tactics that were have applied to meet criteria of trustworthiness. This section unfolds these issues in accordance with Lincoln and Guba's (1985) work, with some reference to both Shah and Corley (2006) and Hayes (2011).

Table 3.7: Techniques and applied tactics to meet criteria of trustworthiness in qualitative research. The table is adapted from Shah and Corley (2006) based on the work of Lincoln and Guba (1985).

Criteria	Recommended techniques	Applied tactics
Credibility	Prolonged engagement	Case study and action research collaboration extending 12+ months
	Persistent observation	Open observation protocol to avoid premature closure in data collection
	Triangulation	Triangulating sources and methods
	Peer debriefing	Peer debriefing sessions with supervisors, co-authors, and other colleagues
	Member checking	Member check focus groups, interviews, and using synthesized analyzed data
Transferability	Detailed (thick) descriptions of research design, data, context, and participants	This chapter and each paper provide detailed (thick) descriptions of research design, data, context, and participants
Dependability	Inquiry audit of the research *process*	Established a meticulous audit trail to ease the inquiry audits, which involved my supervisors
	Purposive and/or theoretical sampling	Purposive sampling of various cases
	Protect informants' confidentiality	Blurring people's identity and not disclosing company names without permission
Confirmability	Inquiry audit of the research *product* (data, findings, intepretations, and recommendations)	Established a meticulous audit trail to ease the inquiry audits, which involved my supervisors
	Keeping a reflexive research journal	I kept a reflexive research journal

Credibility refers to whether the results of qualitative research are credible, believable, and address a real-world problem seen from the perspective of the participants in the research, and whether the results uncover participants' tacit knowledge (G. R. Hayes, 2011).

I accounted for credibility through **prolonged engagement**–as recommended by Lincoln and Guba (1985)–with the large, well-established company, which enabled me to move from being considered an outsider to becoming a trusted insider. I made **persistent observations** by applying an open observation protocol capturing both salient and tacit behavior of practitioners. Persistent observations further ensured that I did not prematurely ignore issues that could evolve and impact UX integration and adoption over time (Nielsen, Skov, & Bruun, 2023). However, very specific technical specifications and trade secrets were not captured in my observations, as such information has no relevance for answering my research questions. I adopted two modes of **triangulation**: triangulating sources (capturing multiple perspectives) and methods (applying various data collection techniques) (Lincoln & Guba, 1985). Frequent **peer debriefing** sessions were held with supervisors, co-authors, and other colleagues to discuss the research design, interpretation of data, reporting of findings, and next steps[12]. These sessions additionally had the function of bouncing off ideas and concerns regarding these aspects. Lincoln and Guba (1985) argue that **member checks** is the most crucial technique for establishing credibility, as data, interpretations, and conclusions are vetted by the very people whom the data were originally collected. As mentioned in Section 3.2.4, I relied on three member check techniques: focus group, interviews, and using synthesized analyzed data (Birt et al., 2016). Lastly, I preserved participants' language and perspectives rather than imposing scientific language and concepts, as recommended by Hayes (2011).

Transferability refers to the recognition that qualitative empirical results are inherently contextualized and oriented towards local issues (G. R. Hayes, 2011). It is therefore crucial that the researcher provides, as transparently as possible, detailed thick–not in an ethnographic sense–descriptions of the research design, how data is collected, analyzed, and described, as well as the context and the people being studied in order to enable other researchers to replicate part of the study in other contexts as well as transfer and relate findings to other contexts (G. R. Hayes, 2011; Lincoln & Guba, 1985; Shah & Corley, 2006).

To account for transferability, this chapter and each of the papers provide detailed accounts of the applied research methods. Furthermore, research findings were discussed and contrasted with established literature in both HRI and HCI. Similarly, I explicitly acknowledge that my research is inherently contextualized and oriented towards local issues, which I see as a strength because it reflects the pragmatic orientation and research methods that I have chosen for my dissertation.

[12]Lincoln and Guba (1985) caution against using debriefers who are too senior or in authority position, as there might be imbalanced power relationship between the person in need of peer debriefing and the debriefer. In Denmark, however, we have a fairly low hierarchy and I had several people to turn to for debriefing to balance this issue.

Dependability refers to stability and traceability of the research with some allowance for instabilities arising as a result of the emergent nature of how qualitative–and pragmatic–research is undertaken (Guba, 1981). Dependability is achieved by transparent data management and detailed accounts of how data are collected, analyzed, and described (G. R. Hayes, 2011; Shah & Corley, 2006; Lincoln & Guba, 1985). The recommended techniques to accomplish dependability are to establish an **inquiry audit** focusing on the research *process* (Shah & Corley, 2006; Lincoln & Guba, 1985), utilizing **purposive and/or theoretical sampling**, and **protecting participants' confidentiality** (Shah & Corley, 2006).

Detailed accounts of the applied and adopted research methods are provided in the included papers as well as outlined in this chapter. I established an audit trail by keeping meticulous records of methodological decisions, raw data, what happened with the data during the analysis (including open coding and theme generation), process notes, reflexive notes and material, as well as records of the instruments themselves (e.g., interview and survey questions). This eased the **inquiry audit** which involved my supervisors. As recommended by Lincoln and Guba (1985), the inquiry audit attended to the research process by considering methodological choices, fairness of the representation of participants and companies, and by ensuring that analyses were not prematurely closed, as this could be a sign of overly relying on my a priori (pragmatic) **experience** and **theory**. As outlined in Section 3.2.2, I primarily used **purposive sampling** to select relevant and information rich cases. **Participants' confidentiality** were ensured by blurring people's faces when using snippets of interactions (Paper 2) and by signing and complying with non-disclosure agreements (Papers 3 and 4). I am, however, allowed to share some company names.

Confirmability refers to the degree to which results can be confirmed and corroborated by others (G. R. Hayes, 2011). One of the techniques to establish confirmability is through **inquiry audits** that focus on the *product* of research, i.e., data, findings, interpretations, and recommendations (Lincoln & Guba, 1985). This, additionally, includes ensuring a clear separation of 1st and 2nd order findings (regarding, e.g., coding structure) (Shah & Corley, 2006). Triangulation, which is also used to establish credibility, and **keeping a reflexive research journal** are likewise techniques to establish confirmability (Lincoln & Guba, 1985).

The inquiry audits were conducted less formally than what is outlined by Lincoln and Guba (1985) in that I continuously discussed, showed, and shared my research plans, processes, data, analyses, interpretations, findings, and recommendations with my supervisors. I was meticulous about data management and recording, which were accomplished by: transcribing interviews verbatim; maintaining consistency in how observations were documented; clearly articulating methodological decisions; and by keeping accurate records of field notes, contacts, and linkages between raw data, codes, and themes in order to clearly separate 1st and 2nd order findings, as recommended by Lincoln and Guba (1985) and Shah and Corley

(2006). Additionally, I gathered large amounts of data to ensure that I had enough evidence to confirm that events transpired as described, as recommended by Hayes (2011). Lastly, as is also good practice in reflexive thematic analysis (Braun & Clarke, 2022), I kept a **research journal** through out my dissertation research.

3.5 Summary

This chapter provided an extensive account of the dissertation's pragmatic research design. It described the pragmatic stance taken and articulated how and why it made sense to position my research as pragmatic. The chapter moreover outlined the two streams of research; **development of the RODECA** and **understanding how robots are developed**, which are present in this dissertation and visualized in Figure 3.2. Furthermore, the chapter provided detailed and factual information regarding case selection and strategies applied to select the cases (summarized in Table 3.2), case companies and developed robots (summarized in Table 3.3 and Table 3.4, respectively), data collection (Table 3.5) and analysis methods (Table 3.6 and Figure 3.5), as well as the researcher's position. The chapter ended with an account of the tactics applied to build trustworthiness and raise the quality of the research (Table 3.7).

Before continuing to the discussion of my research, I recommend that the readers familiarize themselves with the four included papers. To aid this familiarization, the following chapter summarizes each of the papers.

4 PAPER CONTRIBUTIONS

This dissertation addresses the need to understand industry robot design in order to orchestrate and facilitate UX integration and adoption in robotics companies. This is an area of research which has been recognized for its importance, but which has received little attention in HRI (Sandoval et al., 2018). To unfold this issue, this dissertation applied a pragmatic research approach to identify industry robot designers' requirements for HRI design frameworks (RQ1) and examine how organizational mechanisms influence UX integration in robot development processes and adoption in robotics companies (RQ2) and how robotics companies can be supported to integrate and adopt UX (RQ3). Figure 3.2 visualized the two streams of research: **development of the RODECA** and **understanding how robots are developed**, and the connection between the papers and research questions. Figure 1.1 zooms in on the relationship between the papers and the research questions. This dissertation comprises of four research papers, which can be found in Appendix B and which are further described in subsequent sections.

Section 3.2.1 provides an overview of my research, including description of the two streams and an outline of how each paper contributed to the dissertation. To summarize this account, Paper 1 established whether the robotics industry was interested in an HRI design framework and identified key requirements for such a framework based on industry needs and concerns. Born out of the collaboration with on the UX consultancy firms in the pilot project, Paper 2 suggested digital ethnography as an extension to traditional competitor analysis focusing on situated and unguided interactions between robots and people. Papers 1 and 2 contributed to the first stream of research dedicated to the development of the RODECA.

The second stream of research investigated the **situation** RODECA would operate in and identified organizational mechanisms that hindered or facilitated UX integration and adoption based on a longitudinal, extreme case study (Paper 3) and action research (Paper 4) within a robotics company. These studies suggest that, in order to integrate UX within robot development, targeted strategies are needed at three levels: individual, team, and organizational. Additionally, Paper 4 outlined the 21 practical UX strategies we implemented with practitioners to initiate UX integration from a practitioner perspective and how we, as researchers, can help facilitate this process. Paper 3 provided five recommendations for integrating and adopting UX in robot development.

4.1 Paper 1: The Pilot Project and Conceptualization of RODECA

Paper 1

Nielsen, S., Ordoñez, R., Hansen, K.D., Skov, M.B., and Jochum, E.: RODECA: A Canvas for Designing Robots. 2021. In Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction. Association for Computing Machinery, Boulder, CO, USA, 266–270. DOI: 10.1145/3434074.3447173

Existing HRI frameworks for designing robots greatly vary in their scope, ranging from frameworks focusing on a specific aspect of design (e.g., robot behavior (Hoffman & Ju, 2014; Venture & Kulić, 2019)) or on a Participatory Design approach (Azenkot et al., 2016; H. R. Lee et al., 2017; Frederiks et al., 2019) to frameworks encompassing the design process more broadly (Tonkin et al., 2018; Axelsson et al., 2021; Šabanović et al., 2009). However, they have not been applied in industrial contexts to develop new robotic platforms, stop short of encompassing business perspectives, and do not seem to account for practitioners' requirements nor the organizational **situation** wherein the robot development takes place.

In this paper, we carried out a pilot project to gauge interest in an HRI design framework within the robotics industry, and to identify key requirements for such a framework based on industry needs and concerns. This was achieved through two online workshops and an individual company assignment. In the first workshop, I presented our research idea and identified industry partners' requirements for a robot design framework. These insights were synthesized based on a rapid thematic analysis, and used in combination with existing research to conceptualize the framework we call **RODECA**, which is short for **Robot Design Canvas**, shown in (Nielsen, Ordoñez, et al., 2023). The individual company assignment focused on supporting industry partners in applying RODECA to one of their robotics projects. Based on their responses, we identified potential challenges with the initial version of RODECA, which we deliberated on in the second workshop.

We learned that current HRI design frameworks do not sufficiently account for the organizational **situation** wherein the robot development takes place, e.g., regarding business models, project, and product management. This suggests that HRI design frameworks developed in academic contexts might be too generic or too specific and rigid to be applied by industry professionals. Thus, our findings identified a **conflict** between **theory** informed by HRI research and **action** performed by practitioners, and validated what we saw as a weaknesses with existing HRI design frameworks. In addition to the conceptualization of RODECA, we identified four qualities needed in a framework for designing robots, which are summarized accordingly: 1) provide structure to design and development of robots that account for people and context; 2) strengthen multidisciplinary collaboration through a shared language; 3) facilitate market and application exploration; and 4) support competence identification.

The pilot project encouraged a view of HRI design frameworks developed in academia through an industrial lens. Industry partners were supportive of RODECA and saw the value and need for it. There was, however, a risk that we were all projecting our own idealized version of how it would be to apply RODECA without considering the realities, i.e. the **situation** wherein their robot development takes place. At this point in my Ph.D. (late 2020), there was not a large body of research on how robotics companies work with UX and development akin to the extensive research on UX integration in software development from where we could draw inspiration. Thus, to increase relevance and applicability of RODECA to the robotics industry, we have to better understand the **situation** wherein robots are developed and the professionals involved. This pilot project thus helped direct subsequent research towards making this **situation** more conducive to UX, and not just to one specific framework.

4.2 Paper 2: Digital Ethnography - Extending Competitor Analysis

Paper 2

Nielsen, S., Skov, M.B., Hansen, K.D., and Kaszowska, A.: Using User-Generated YouTube Videos to Understand Unguided Interactions with Robots in Public Places. 2023. In ACM Transaction on Human-Robot Interaction. DOI: 10.1145/3550280

Disclaimer: *This study was initially conducted in collaboration with one of the UX consultancies in the pilot project, and sought to address the need for HRI design frameworks to support market and application exploration. The peer review process required that we omitted details about the collaboration with the company and focused entirely on the methodology, and this is evident in the paper.*

With the increasing rate at which professional and personal social service robots are deployed in public places, robot designers must account for the complex encounters taking place in those environments. However, robots are often too immature to provide expected services, making people doubt the robot's capabilities (Rieg, Carter, Fong, Forlizzi, & Steinfeld, 2021) and refuse to accept and interact with the robot (Shiomi et al., 2008). Equipping robots with expectancy-setting and recovery strategies can alleviate the negative impact that interaction breakdowns have on user experience (M. K. Lee, Kiesler, Forlizzi, Srinivasa, & Rybski, 2010). However, the type of interaction breakdowns and how people overcome them during unguided interactions with robots in real-world **situations** have received little attention.

We addressed this gap by examining characteristics of unguided interactions and interaction breakdowns in public places between people and robots based on user-generated content uploaded to YouTube in a covert, non-participant digital ethnographic study (Nielsen, Skov, Hansen, & Kaszowska, 2023). We adopted digital ethnography as it allowed us to explore interactions up-close without the risk of interference. Data gathering comprised of a search phase and a filtering phase. For our search, we applied purposeful sampling using one search phrase, similar to (Paay, Kjeldskov, & Skov, 2015; Blythe & Cairns, 2010, 2009), as well as combined technology-oriented terms with case-specific keywords, as suggested in (Komkaite, Lavrinovica, Vraka, & Skov, 2019; Anthony, Kim, & Findlater, 2013). We included YouTube's suggestions for the next videos to broaden the search. A stop criterion was imposed, as recommended in (Anthony et al., 2013). The filtering phase comprised of an initial screening and an eligibility selection (Nielsen, Skov, Hansen, & Kaszowska, 2023). Videos that disturbed the chronological order of events and where it was difficult to capture the essence of the interaction were excluded, as recommended in (Jewitt, 2012). We screened a total of 560 videos and arrived at a sample of 104 usable YouTube videos, which we analyzed through deductive and inductive qualitative content analysis (QCA). For the deductive QCA, we applied the same high-level categories and some sub-categories as in (Komkaite et al., 2019; Anthony et al., 2013) with appropriate rephrasing. Additional sub-categories and codes were defined through the inductive QCA. Two coders were trained to apply the coding scheme on a representative sample. Confusion and disagreements were resolved resulting in a refined coding scheme, which they applied to a randomly selected sample from the remaining videos. An intercoder reliability check using Krippendorff's alpha (A. F. Hayes & Krippendorff, 2007) demonstrated very high agreement ($\alpha = 0.96$). Thus, one coder applied the revised coding scheme to the remaining videos (Nielsen, Skov, Hansen, & Kaszowska, 2023).

We examined unguided interactions between people and 17 different service robots. From these interactions, we observed six person-initiated interaction breakdowns and three environmental disturbances that had a direct, negative effect on the ongoing unguided interaction as these breakdowns delayed, prolonged, or ended the interaction (Nielsen, Skov, Hansen, & Kaszowska, 2023). Person-initiated interaction breakdowns pertained to a) kids blocking, slapping, or hugging robots; b) people squeezing in when others interacted; c) people intervening or overtaking an ongoing interaction, not to help; d) people waiting close by for their turn to interact with the robot; and e) adults deliberately getting in the way of the robot; and f) the primary user breaking down the interaction on purpose (Nielsen, Skov, Hansen, & Kaszowska, 2023). Environmental disturbances were caused by a) false positives where the robot abruptly stopped for no apparent reason; b) InCoPs getting too close to the robot; or c) other objects. Additionally, we identified active (primary and secondary) users, inactive (commentators and observers) 'users', and InCoPs all influencing unguided interactions through different group configurations (Nielsen, Skov, Hansen, & Kaszowska, 2023).

Our findings underline the importance of not treating the concept of a 'user' as static when designing robots for public places, considering that a person can move between user roles and partake in various group configurations. This suggests that robots should not be designed with only the primary user in mind, because in public places the primary user of a service robot is unlikely to be the person whom the robot encounters the most (von der Puetten et al., 2020). Instead, we recommend that robot designers consider designing their robots to support multi-user scenarios and different user roles.

This paper offers a methodology that can extend traditional competitor analysis and support robotics companies in integrating UX insights into robot development, much like what Levy (2021) suggest for UX. It focuses on central aspects of robot design such as the physical design of the robot (appearance and movement capabilities), interaction and communication capabilities, and, most importantly, people's situated interactions with robots and the dynamics of such interactions. Furthermore, Laursdottir et al. (2017) recommend using alternative channels for incorporating user feedback into agile development, and propose the use of social media, user forums, or tweets to represent the user. We propose digital ethnography as a means to perform user research, e.g., as part of upfront design activities, without having access to authentic users and functioning robots, as it is based on user-generated content uploaded to YouTube (other social media platforms could be considered as well). Additionally, digital ethnography can supplement in-situ context exploration and need finding phases, and contribute empirical data when defining preliminary user requirements for robots and, potentially, when defining UX goals and metrics for robots.

4.3 Paper 3: User Experience in Large-Scale Robot Development

Paper 3

Nielsen, S., Skov, M.B., and Bruun, A.: User Experience in Large-Scale Robot Development: A Case Study of Mechanical and Software Teams. 2023. In Human-Computer Interaction INTERACT'23. DOI: 10.1007/978-3-031-42283-6_3

In order to support integration and adoption of UX across multidisciplinary teams working within robotics, we must better understand how robotics companies develop robots and account for UX in the process. While integrating UX into industry practices is a well-researched topic for agile software development (e.g., (Ananjeva et al., 2020; Persson et al., 2022; Garcia et al., 2019; Wale-Kolade et al., 2013)), little is known about how UX integration and adoption "works" at the intersection of physical robot development and software development.

Through a case study, we examined how technical teams embedded UX in robot development. In the paper (Nielsen, Skov, & Bruun, 2023), we argued that this was an extreme case as it addressed the deeper causes and consequences of how software and mechanical teams worked with UX; thereby, providing new perspectives to HCI research, which hitherto has concentrated predominantly on UX integration from UX specialists' and software developers' perspectives. The primary empirical data from this study comprises extensive non-participant observations of 30 scrum meetings over the course of six months. More than 40 domain experts participated in these scrum meetings. We arranged follow up sessions with product managers to clarify cases of doubt and used presentation slides, documents (e.g., user stories), and practitioners' email correspondence as supplementary data. We also had access to their project management tool (Jira), which provided insights into coordination of implementation tasks. Data were analyzed according to a three-level structure beginning with naïve reading of data to get a sense of relevant units of meaning. Second, themes were developed and refined through a structural analysis that alternated between what participants said and what was observed. This step was carried out by the first author and two senior HCI researchers. Third, themes were interpreted and discussed in relation to existing literature (Nielsen, Skov, & Bruun, 2023). The paper presents four themes concerning the role of UX in robot development, workarounds in design evaluation, requirements handling, and coordination mechanisms (Nielsen, Skov, & Bruun, 2023).

Our work presents four major findings pertaining to 1) the role UX plays in robot development; 2) workarounds mechanical and software teams utilize in design evaluations; 3) teams' sensitivity towards listening to authentic users when dealing with requirements; and 4) teams' coordination mechanism. We observed that teams had an ad-hoc approach to UX and that they often made compromises (e.g., testing on laptops rather than with the actual robot). UX appeared to be compartmentalized across teams, which increased the risk that essential robot attributes, such as behavior, intention markers, and social skills, were overlooked. Our observations further revealed that the mechanical team had a clearly defined development process, which included prototyping, experimentation, and parallel design tracks, and standardized coordination mechanisms compared to the software team, who worked toward establishing similar practices within their team with varying success. From this case study, we formulated five practical recommendations for robot development teams, which we summarized accordingly: "1) identify coordination mechanisms to improve UX in robot development; 2) align coordination mechanisms to avoid changing design decisions post hoc; 3) align, establish, and define stage-gate transition outputs critical for UX, mechanical, and software development; 4) ensure easy and equal access to physical robot prototypes to support UX evaluation with authentic users; and 5) establish UX goals and metrics using robot design canvases (Axelsson et al., 2021; Nielsen et al., 2021) and metrics developed to assess UX of robots (Wallström & Lindblom, 2020)" (Nielsen, Skov, & Bruun, 2023, p. 57).

This case study underscores the importance of understanding the complexity of the development **situation** that robotics companies face. Specifically, this company has longstanding traditions for developing mechanical products and, according to the project manager, this was the first time a dedicated software team was involved in a cross-functional machine development project. This likely explains our observation that the mechanical team had a clearly defined development paradigm (following their industry standards: New Product Development), as opposed to the software team, which was in the process of attuning software development practices to fit with New Product Development in the context of robot development. Other mechanisms which contributed to the complexity of this development project were: team constellation and physical placement of the large number of domain experts (which we simplified in the paper), collaboration and coordination with external partners, limited access to robots, and management's influence and prioritization (which we did not explore in this paper). Taken together, these mechanisms might explain the observed compartmentalization and de-prioritization of UX. To combat this, we argue for practical and contextualized strategies for UX integration within robot development and adoption across the organization, such that UX becomes a fundamental part of robot development.

4.4 Paper 4: UX Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Robotics Company

Paper 4

Nielsen, S., Ordoñez, R., Skov, M.B., and Jochum, E.: Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Large Organization Developing Robots. 2023. In Journal of Behaviour & Information Technology. Taylor & Francis Group. DOI: 10.1080/0144929X.2023.2227284

Developing robots that generate value for people in commercial and consumer contexts is a difficult task for robotics companies, and the intended value rarely materializes (Sandoval et al., 2018; Tulli et al., 2019; Weiss & Spiel, 2022). Researchers have long advocated for the integration of UX in robot development (Tonkin et al., 2018); however, the actual robot design process, as well as how practitioners can utilize design insights and involve authentic users, have received limited attention (Sandoval et al., 2018).

We carried out action research (AR) together with an industry partner focusing on how UX integration and adoption works within a robotics company (Nielsen, Ordoñez, et al., 2023). AR was considered the ideal research method for this study, as the objective was to insert changes to local and immediate industry needs, where current knowledge and practices were inadequate for addressing the problems at hand (Kidd & Kral, 2005). We adopted McKay and Marshall's (2001) dual cycle approach to AR, which implied a close collaboration between practitioners and researchers who relied on each other's skills, experiences, and competencies to bring about changes. The dual cycle approach allowed for working with company specific problem-solving interests to produce practical outcomes and research interests guided by research questions to produce knowledge relevant for an academic audience. A UX maturity assessment (Pernice, Gibbons, Moran, & Whitenton, 2021) was made to better understand the problems experienced by the company regarding UX integration and adoption. The practitioners and I identified key concerns that this AR should address: 1) planning and executing UX activities that aligned with the general project plan and implementation plans; 2) UX competence-building; and 3) cultivating corporate UX. These concerns were addressed through six interventions outlined in the paper (Nielsen, Ordoñez, et al., 2023). We observed 65 meetings with 29 people attending. Practitioners completed a survey after each intervention inquiring into their experiences, as recommended in (Pedersen, Sørensen, Stage, & Høegh, 2021; Varsaluoma & Sahar, 2014). I kept a journal for noting my experiences, ideas, impressions, and reflections, as recommended in (Braun & Clarke, 2022). Data were analyzed through inductive reflexive thematic analysis (Braun & Clarke, 2022) informed by the research questions and industry problem-solving interests.

The paper provides a contextualized examination of UX integration and adoption within a robotics company (Nielsen, Ordoñez, et al., 2023). We identified individual, team, and organizational level behaviors that formed six barriers concerning: confidence, commitment and support structures, trade-offs in UX, handover practices, UX management paradigm, and trust in UX, which impeded UX integration and adoption (Nielsen, Ordoñez, et al., 2023). The barriers are analytical aggregations of observed behaviors. Together with practitioners, we implemented 21 targeted strategies for strengthening UX competencies and cultivating corporate UX. These strategies were informed by the researcher's and practitioners' **theory** in response to the **qualities** of **experienced conflicts**.

The most substantial impact this study made, according to a product manager, is that it de-risked the design process and provided ways to work with UX in uncertain **situations** (Nielsen, Ordoñez, et al., 2023). This study made it clear that HRI design frameworks have a better chance for generating industry impact if they concentrate on strategies for maturing and de-risking UX in robot development, rather than proposing new design processes to follow. That is, our findings showed that practitioners were not ready to absorb HRI design frameworks such as RODECA presented in (Nielsen et al., 2021), the canvases proposed by Axelsson et al. (2021), nor the methodology proposed by Tonkin et al. (2018). Instead, the robotics industry is better severed with a canvas of contextualized UX strategies that facilitate UX integration within development and adoption at individual, team, and organizational levels, which enable the company to mature, such that they in the future are able to apply HRI design frameworks. This study took the first steps towards the development of a strategic HRI design framework by proposing 21 targeted and applied UX strategies.

5 DISCUSSION

This dissertation applied a pragmatic research approach to UX of social service robotics, identifying industry robot designers' requirements for HRI design frameworks (RQ1), examining how organizational mechanisms influenced UX integration in robot development and UX adoption in robotics companies (RQ2), and exploring how robotics companies can be supported to integrate and adopt UX (RQ3). The connection between the included papers and the research questions were visualized in Figure 1.1 and Figure 3.2, and summarized in the previous chapter. This chapter discusses the findings in relation to the three research questions. Throughout this dissertation, I have argued that UX is multifaceted and needs to be considered as such for UX integration and adoption to generate lasting impact. This chapter discusses the four identified requirements industry robot designers have for HRI design frameworks in relation to the HRI design frameworks presented in Section 2.1. This is followed by a discussion of the practical applicability of HRI design frameworks in light of these requirements. Afterwards, I discuss the seven identified organizational mechanisms' influence on integration and adoption of UX in a large, well-established robotics company (R4) and what implications these mechanisms carry for the design of robot attributes, and 18 strategies that can support robotics companies to integrate and adopt UX. Lastly, the chapter discusses the limitations and proposes directions for further research.

5.1 Requirements for HRI Design Frameworks

Industry robot designers need research-based guidance on how to choose and apply relevant and correct UX techniques and methods, and such techniques and methods should have practical applicability (Lindblom & Andreasson, 2016). However, there has not been much focus on identifying and accounting for industry robot designers' requirements leading up to the development of HRI design frameworks despite researchers arguing that we need to understand the **situation** practitioners work in to bridge HRI theory and practice (Cila et al., 2024; Buchner et al., 2012). To address this shortcoming, the pilot project identified industry robot designers' requirements for HRI design frameworks and synthesized these requirements in a new framework: RODECA (Nielsen et al., 2021). Table 5.1 summarizes the requirements that industry robot designers value in HRI design frameworks based on (Nielsen et al., 2021) and compares them to relevant literature, which this section further discusses.

5.1.1 Provide structure to robot design and development

The HRI design frameworks (including the universal design practices applied in HRI) presented in Section 2.1 provide some structure to robot design but do not extend beyond the

Table 5.1: Identified requirements that industry robot designers have for HRI design frameworks (Paper 1, Nielsen et al., 2021) compared to the HRI design frameworks presented in this dissertation.

Requirements for HRI design frameworks	Addressed by...
Provide structure to design and development of robots that solve problems for real people in the actual context	They provide structure to the design process, but rarely address implementation
Strengthen multidisciplinary collaboration within robot design teams and strengthen engagement with authentic users through a shared language	Forming a shared language is embedded in the Outside-in design approach (Šabanović et al., 2009) and in Participatory Design (H. R. Lee et al., 2017; Nanavati et al., 2023; A. Rogers Wendy et al., 2022; Winkle et al., 2021). The UX of HRI design methodology (Tonkin et al., 2018), the social robot co-design canvases (Axelsson et al., 2021), and the Design Thinking approach (McGinn et al., 2020) are suited for multidisciplinary robot design teams
Facilitate market and application exploration	Identifies commercial applications (Tonkin et al., 2018; Khan & Germak, 2018; McGinn et al., 2020); examines other technologies (McGinn et al., 2020; Axelsson et al., 2021; Šabanović et al., 2014); and benchmark (Wallström & Lindblom, 2020; McGinn et al., 2020)
Support competence identification	Not covered in today's HRI design frameworks

prototyping phase and thus do not address actual development of entirely new robots developed for commercial purposes. That said, a few HRI design frameworks bridge the design phase with preliminary development by having roboticist or other technical experts derive technical specifications and assess feasibility from upfront design activities (Axelsson et al., 2021; Lohse et al., 2014; Nanavati et al., 2023; Zhong & Schmiedel, 2021; Winkle et al., 2021; Tonkin et al., 2018). A possible explanation why most HRI design frameworks do not consider how outcomes from upfront-design activities can be implemented in actual development is that they often customize an existing commercial robot platform, which only requires changes to the software. In other cases, researchers provide best practices for utilizing Participatory Design (A. Rogers Wendy et al., 2022), evaluating UX in HRI (Weiss et al., 2011; Wallström & Lindblom, 2020), and for designing robots' communicative signals (Holthaus et al., 2023), which are not linked to specific robots. Conversely, the HRI design frameworks developed and/or applied by Lee et al. (2017), Šabanović et al. (2014), McGinn et al. (2020), Khan and Germak (2018), and Hoffman and Ju (2014) are utilized in developing new robots, implying that technical implementation and mechanical design considerations are somewhat accounted for. However, those robots are sophisticated prototypes and proof-of-concepts, and researchers seem to concentrate on creating standalone, unique robots, which may make these frameworks too specific to be applied by industry robot designers.

While today's HRI design frameworks meet the requirement to provide structure to robot design, they do not sufficiently account for development. Consequently, it is challenging to see how these HRI design frameworks enable robot design teams to progress beyond prototyping and evaluation of high-fidelity, functional prototypes to implementing outcomes from upfront design activities when developing new commercial robots. Additionally, these frameworks do not seem to bridge technical development of entirely new robots, UX, and business objectives; a shortcoming pointed out by Sandoval et al. (2018). RODECA presents a first version of a design framework addressing these three aspects: Business objectives is covered in **Planning & Preparing**; UX is covered in **Context Exploration**, **Specify Robot Goals**, **Design with Users & InCoPs**; and technical development is covered in **Develop the Robot**. Additionally, RODECA pays attention to the design of **Robot Attributes** to acknowledge the important work of HRI researchers. RODECA is further discussed in Section 5.5.1.

5.1.2 Strengthen multidisciplinary collaboration in robot design teams

Given this dissertation, it is not surprising that industry robot designers need HRI design frameworks to strengthen multidisciplinary collaboration in robot design teams, as successful market entry requires contributions from various disciplines. This necessitates careful management of coordination and collaboration between teams to avoid segmentation (Axelsson et al., 2021; Šabanović et al., 2009). Some HRI design frameworks are deliberately geared to strengthen multidisciplinary collaboration with industry practitioners, such as the UX of HRI design methodology (Tonkin et al., 2018), the social robot co-design canvases (Axelsson et al., 2021), and the Design Thinking approach applied in (McGinn et al., 2020), whereas others support researchers from across disciplines (Šabanović et al., 2009). Similarly, forming a shared language is embedded in Participatory Design (H. R. Lee et al., 2017; Nanavati et al., 2023; A. Rogers Wendy et al., 2022; Winkle et al., 2021).

Building a common language shared by the entire robot design team ideally occurs through the application of the framework (Šabanović et al., 2009; Axelsson et al., 2021). Given that industry robot designers require this from frameworks, it is important to emphasize it explicitly. RODECA makes it an explicit part of the framework, emphasizing that it should be handled deliberately rather than coincidentally. This does not mean that forming a shared language (included as 'create a common language within the Team based on the user observation') should only happen during **Context Exploration**. It was included to indicate when it is advisable to start acting on it if it has not happened yet. Ideally, forming a shared language happens and evolves throughout the design and development of the robot.

The literature links the forming of a shared language to avoiding terminology disputes and establishing a shared product vision, rather than dealing with coordinating UX and merging distinct development processes, which my research shows is critical for UX integration and adoption in robotics companies. How my research addresses UX coordination in robotics companies beyond that of terminology disputes is discussed in Section 5.3.3 and Section 5.5.4, while Section 5.3.4 and 5.5.5 tackle the issue of merging development processes.

5.1.3 Facilitate market and application exploration

Many HRI design frameworks advocate for a thorough exploration of the application context (i.e., the context the robot will be deployed) and identification of issues and needs of authentic users (e.g. (Winkle et al., 2021; Axelsson et al., 2021; H. R. Lee et al., 2017; Šabanović et al., 2014; Tonkin et al., 2018; Khan & Germak, 2018; McGinn et al., 2020; Buchner et al., 2012)). Few cases address identifying a viable commercial application for their robots (Tonkin et al., 2018; Khan & Germak, 2018; McGinn et al., 2020). Instead, these explorations primarily aim to define the robot's purpose, functionality, and features rather than exploring the market by investigating other technology solutions targeting the same context.

However, some exceptions exist where existing technology solutions in the application context were considered in order to assess the robot's potential to mitigate current solutions' shortcomings. For example, McGinn et al. (2020) included a benchmarking stage in their robot design process, assessing how current technology solutions addressed the identified use cases. This informed the specification of requirements the robot had to satisfy and to which existing solutions were benchmarked, which helped the robot design team identify a novel opportunity for their robot, which integrated with existing technology devices. Similarly, some of the social robot co-design canvases prompt robot designers to consider the advantages the robot should deliver compared to computer or a human ('Problem Space'-canvas) in a specific environment ('Environment'-canvas) and the service ecosystem the robot will be linked to, which includes whether the robot connects to other systems when operating (Axelsson et al., 2021). Šabanović et al. (2014) explored design alternatives to justify whether an embodied and socially interactive robot would provide 'more' value compared to simpler solutions. The goal was to understand how variations in the design of robot attributes influenced the users' experience. Additionally, the authors list examples of other technologies developed for the same application area (Šabanović et al., 2014).

HRI design frameworks do not consider application exploration from the perspective of systematically exploring what else is on the market to identify a potential viable business case, which is what robotics companies want (Nielsen et al., 2021). Robotics companies want to deliver a product that is better than the competition (R2 and R4) or create an entirely new market (R1). However, the examples discussed in this section are worth considering as they can support industry robot designers in empirically justifying whether certain design decisions increase the likelihood that the robot generates commercial value while delivering value to authentic users cost-efficiently. This could help robotics companies avoid over-engineered solutions and feature creep, a frequently recurring issue in robotics companies (Dietrich et al., 2021). Robot designers would do well to adopt a systematic approach to benchmarking existing technology solutions and their own robots, as suggested in (McGinn et al., 2020; Wallström & Lindblom, 2020). This aspect is further discussed in Section 5.3.7 and 5.5.8.

5.1.4 Support competence identification

Identifying the necessary competences at each stage of robot development is not addressed in today's HRI design frameworks, although researchers report the professional backgrounds of those involved in developing and applying the frameworks. While "outside" domain experts, who are not researchers, are often involved in applying HRI design frameworks (e.g. (Winkle et al., 2021; Axelsson et al., 2021; H. R. Lee et al., 2017; McGinn et al., 2020; Tonkin et al., 2018; Cila et al., 2024; Šabanović et al., 2009; Hoffman & Ju, 2014; Zhong & Schmiedel, 2021; Buchner et al., 2012; Wallström & Lindblom, 2020)), guidance on identifying relevant competences for each development stage is not provided. Bruun et al. (2018) mapped the activities and responsibilities of UX specialists according to three agile software development phases: Inception and elaboration, construction, and transition. They found that UX specialists' involvement in development drop to about 20% during the construction phase, when actual development and implementation of upfront design begins (Bruun et al., 2018). This approach could be used to identify the competences needed throughout robot development and the activities and responsibilities of each profession at each stage. Cila et al. (2024) provide insights into what is expected of UX specialists in robot development: "[...] anticipate and explore user needs, experiences, behaviors, and cognitive abilities, leveraging these insights to craft robotic artefacts that are useful, usable, and user-friendly. Their design considerations span the robots' operating system, interface, form, configuration, sound, and movement" (Cila et al., 2024, p. 138). Competence identification is partly addressed in RODECA as part of the **Planning & Preparing**-building block ('what resources do we have available?' where 'expertise' is listed as a resource to consider). However, this does not provide a clear overview of who is ideally needed for each stage of robot development, but rather which competences the company has access to for a given project (Nielsen et al., 2021).

While practitioners in the pilot project articulated the need to identify which competences were needed for each development stage (Nielsen et al., 2021), my research focuses on UX competences and how to build UX competences in cases where robotics companies do not have UX specialists involved in the project (Nielsen, Ordoñez, et al., 2023). Section 5.3.2 and Section 5.5.3 discuss this issue further. Consequently, identifying the competences ideally needed for each stage of robot development remains an open issue for further research.

5.2 Practical Applicability of HRI Design Frameworks

A majority of HRI design frameworks produce specific design-instances, representing unique standalone solutions; that is, domain-specific robots created for very specific problems (Lupetti et al., 2021), which are often research-led. The HRI literature rarely discloses the underlying development paradigms of these frameworks, which makes it challenging for industry robot designers to discern whether they work in practice. For example, Axelsson et al. (2021) took inspiration from the **Business Model Canvas** (BMC) (Osterwalder, 2004) in developing the social robot co-design canvases, but these canvases do not connect to business aspects included in the BMC. The UX of HRI design methodology (Tonkin et al., 2018) is based on Lean UX, Design Thinking, Lean Start-up, and agile methodology, which presumably makes this framework easier to integrate with most design processes used by organizations (Tonkin et al., 2018). Additionally, practical information about what to do and the expected outcomes for each stage is provided in the paper (Tonkin et al., 2018). Also, Zhong and Schmiedel (2021) provide an example of how a social robot deployed in a reception area can be designed using a human-centered agile approach based on formative usability evaluations.

These sparse accounts of the underlying development paradigms of HRI design frameworks are inadequate for facilitating practical application in a real-world robot development. The provided examples demonstrate ways of merging HCD approaches with robot development; however, they all rely on commercially available robots (Furhat and MiR200 (Axelsson et al., 2021), PAL REEM (Tonkin et al., 2018), and Pepper (Zhong & Schmiedel, 2021)), which makes them more akin to software development projects than robot development projects. By relying on a commercially available robots, the robot design team avoid most issues related to mechanical, hardware, electrical, and supply chain that arise when developing entirely new robots. This might prevent the application of HRI design frameworks in robotics companies, as much of the robot development process follow predefined checklists (Wallström & Lindblom, 2020) or, as my research showed, relies on a different development paradigm (Nielsen, Skov, & Bruun, 2023). It is therefore difficult to discern how today's HRI design frameworks would work within robotics companies that develop entirely new robots. Thus, for current and future HRI design frameworks to become attractive and applicable to industry robot designers, I recommend that HRI researchers:

1. Make the underlying development paradigm(s) clearer to help industry robot designers assess whether a HRI design framework fit their **situation** and development practices

2. Make room for flexibility and modifiability by clarifying which parts of the HRI design framework are essential and non-negotiable and where adjustments can be made
3. Emphasize the practical integration and implications of HRI design frameworks

A majority of HRI design frameworks do not explicitly state which development paradigm(s) they link to, except from those discussed above that align with agile development (Zhong & Schmiedel, 2021; Tonkin et al., 2018). However, robots are not exclusively developed according to agile development principles, especially not in mechanically founded companies that follow New Product Development (Nielsen, Skov, & Bruun, 2023). Merging these paradigms can have severe implications for design decisions (Øvad & Larsen, 2015; R. G. Cooper, 2014), which my findings show applies to the design of social service robots as well (Nielsen, Skov, & Bruun, 2023). This can result in robot designers, particularly mechanical designers, making hasty design decisions that are economical and allow them to keep up with the pace of agile software developers, but those decisions may not favor users' needs. This is why it is important that HRI researchers clarify the underlying development paradigm(s) to help industry robot designers assess whether a HRI design framework fit their current **situation** and development practices, which might reduce the risk of making suboptimal design decisions. The issue of robot development is further discussed in Section 5.3.4 and Section 5.5.5.

Industry robot designers might find it easier to adopt HRI design frameworks during the discovery phase as part of upfront design activities, as they are in "discovery mode". However, as the project progresses, it may become more challenging or less likely that practitioners adopt theoretical frameworks unless they are deliberately tailored to their processes and the specific development stage (Remy, Gegenbauer, & Huang, 2015). My findings suggest that UX practitioners become more risk-averse and do not want to disturb the 'flow' in the company (Nielsen, Ordoñez, et al., 2023). Upfront design activities are often treated separately from development, but once the project progresses to the actual development, UX practitioners tend to adjust their practices to fit the overall scope and development paradigm to have the slightest influence on the final product (Nielsen, Ordoñez, et al., 2023). Consequently, when HRI design frameworks do not have a well-established track record of successful industry cases, industry robot designers may be less willing to take the risk of utilizing such frameworks, especially if the framework does not match the chosen development paradigm. Despite practitioners acknowledging the value of design methods, tools, and frameworks originating in research, as well as research insights themselves, they are rarely adopted in industry practices because they fail to account for the practicalities of the **situation** (Remy et al., 2015; Gray, Stolterman, & Siegel, 2014). UX specialists both consciously and unconsciously "co-opt" design methods in order to opportunistically fit their current situation, resources, ways of working, and client-relationship (Gray et al., 2014). In this process, a single method or tool is rarely sufficient to meet the needs of a given design situation, resulting in UX specialists selecting and combining multiple methods and tools in an ad-hoc, abducitve, and highly situated manner (Gray et al., 2014). This is why I recommend that HRI researchers make room for flexibility and modifiability in their frameworks by clarifying which parts are essential and non-negotiable and where trade-offs can be made.

HRI theory should ideally inform HRI practice and the design of robots (Cila et al., 2024). However, research is often insulated from the 'real-world' messiness, as insights from HRI research are based on experimental conditioners intended for generalizability, which may not easily transfer to real-world robot development. Cila et al. (2024) emphasize the importance of engaging with industry practitioners during actual robot development in order to investigate how HRI theory can influence HRI practice. Conversely, the real world is complex and messy with uncontrolled variables, which may prevent the abstraction of knowledge and methods of practice feeding into formalized theories, thus preventing practice from influencing theory. While bridging research and practice is not unique to HRI, Cila et al. (2024) argue that barriers to the mutual shaping of knowledge generation and practice are also present in HRI and the robotics industry. This is why it is important for HRI researchers to emphasize the practical integration and implications of HRI design frameworks.

The lived **experiences** of industry robot designers are largely overlooked in HRI research, a gap my research addresses. Failure to account for these **experiences** can lead researchers to make assumptions about practitioners' needs, which align more closely with the researchers' own **situation** rather than the actual **situation** of practitioners (Goodman, Stolterman, & Wakkary, 2011). When researchers conceptualize how 'design' transpires in industry, they tend to over-generalize and pay little attention to the practical challenges imposed on design work (Roedl & Stolterman, 2013). This is a criticism I have of existing HRI design frameworks. These frameworks often presume ideal scenarios where practitioners are well-resourced financially, have ample time for elaborate upfront user research, and have access to an almost endless pool of experts (Nielsen et al., 2021). Similarly, there seems to be an assumption that not only the design team but also the wider organization supports the adoption of the HRI design framework in question (Nielsen, Ordoñez, et al., 2023). In the case study and action research collaboration, we uncovered tensions that arise when integrating and adopting UX in a robotics company (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023), which reveal several mechanisms that influenced UX integration and adoption. These mechanisms are discussed at length in the following sections.

5.3 Mechanisms that Influenced UX Integration and Adoption

This dissertation distinguishes between **integration**, which involves incorporating UX practices and processes into the existing robot development workflow, and **adoption**, which involves efforts towards gaining practitioners' acceptance of these practices and processes. The research presented in the case study (Paper 3, (Nielsen, Skov, & Bruun, 2023)) and action research (Paper 4, (Nielsen, Ordoñez, et al., 2023)) demonstrated that focusing exclusively on integration is insufficient if the goal is to generate lasting impact. Both integration and adoption need to be considered, and this has not been sufficiently addressed in HRI research. Although the dissertation distinguishes between integration and adoption, my research has shown that they cannot and should not be disentangled. Integration issues likely have indirect implications on adoption, and vice versa. This discussion focuses on the 21 **barriers** that influenced UX integration (14 barriers) and adoption (7 barriers), and emphasizes whether a barrier primarily influenced integration (**int**) or adoption (**ado**). Section 5.5 discusses opportunities for supporting robotics companies when integrating and adopting UX.

Based on my research, I have identified seven organizational mechanisms that influenced the integration of UX in robot development and adoption of UX in robotics companies:

1. **Commitment and support structures**
2. **UX as a skill set**
3. **Coordination of UX**
4. **Robot development processes**
5. **Policies for user involvement**
6. **Understanding authentic users**
7. **Contextual integration**

These mechanisms are organized into foundational elements (**commitment and support structures** and **UX as a skill set**), operational aspects (**coordination of UX** and **robot development processes**), user-focused aspects (**policies for user involvement** and **understanding authentic users**), and **contextual integration**. To integrate and adopt UX effectively, robotics companies must first establish foundational elements, as they provide the necessary base for coordinating UX and merging robot development processes. With these operational aspects in place, robotics companies can focus on user involvement and understanding authentic users. Finally, addressing contextual integration ensures robots are designed for their specific social environments. This discussion is based on findings from the case study (Nielsen, Skov, & Bruun, 2023) and action research collaboration (Nielsen, Ordoñez, et al., 2023), which provided a rich, contextualized understanding of how robots were developed in a large, well-established robotics company (referred to as R4) and investigated how organizational mechanisms influenced UX integration in a robot development process and adoption in this organization. These findings are discussed against literature.

5.3.1 Commitment and support structures

Existing literature on UX integration and adoption in software development mainly focuses on integration barriers experienced by UX specialists, and less so on how UX is adopted at the cultural level. Colusso et al. (2017) highlight that researchers often overlook contentious stakeholder situations and the influence of legacy culture on design decisions. My research demonstrates the necessity of accounting for organizational culture when supporting a company's integration and adoption of UX. The organizational mechanism that had a substantial influence on culture was **commitment and support structures**. This mechanism highlights organizations' and individual practitioners' commitment to UX and how UX was perceived in an environment where it was not a high priority and where there was little trust in UX. Priority given to UX and trust are intertwined. Lack of trust in UX results in UX not being prioritized, while when UX is not a high priority, it is insufficiently funded and carried out by inexperienced practitioners, leading to questionable techniques and outcomes. My research identified five **barriers** that influenced **commitment and support structures** which, along with **coordination of UX**, influenced the establishment of a UX-friendly culture:

1. UX is verbally supported but the support does not transfer to practice (ado)
2. Managers' views of UX transmit to teams they manage (ado)
3. Trustworthiness and priority given to UX outcomes depend on who participates in user studies (authentic users vs. expert stakeholders) (ado)
4. Insufficient UX budget spread across teams (ado)
5. Internal conflicts hindered UX from being a coordinated effort among individuals and teams (ado)

The organizational culture observed in R4 posed barriers that made the culture antagonistic to UX adoption. Senior managers and developers verbally supported UX and saw it as an opportunity to spot surprises early and inform design decisions, but this sentiment did not translate to practice (Paper 3, (Nielsen, Skov, & Bruun, 2023)). A consequence of UX not being sufficiently prioritized was, according to product managers, that the company did not deliver up-to-date UX, which resulted in loss of customers. That UX is verbally supported by executives and developers but falling short in practice has also been found in software development (Bang, Kanstrup, Kjems, & Stage, 2017; Wale-Kolade et al., 2013).

In Paper 4, we argue that senior management's views of UX transmit to the teams they manage (Nielsen, Ordoñez, et al., 2023). If senior management neglects the value UX can generate when supported, it becomes increasingly challenging to secure colleagues' commitment and support. Consequently, project and organizational changes resulted in sacrificing UX, which severely impacted progress and led to the misconception that UX could harm product development(Nielsen, Ordoñez, et al., 2023). Lack of commitment and support structures ingrained a perception that UX was of lesser value and could be disregarded if nothing valuable was to be learned from it (Nielsen, Ordoñez, et al., 2023). When workload increased and deadlines approached, UX became a matter of ticking off 'users' had been involved (Nielsen, Ordoñez, et al., 2023). Rushing UX is not uncommon when workload increases and there is insufficient organizational support (Carlgren, Elmquist, & Rauth, 2016). UX practitioners consequently fell back to familiar routines, as was the case in (Rosenberg et al., 2015).

Trustworthiness and priority given to UX outcomes depended on who participated in user studies, specifically whether participants were internal or external expert stakeholders or authentic users (Nielsen, Ordoñez, et al., 2023). The former carried more weight. This could indicate that practitioners and stakeholders were unwilling to make changes to the product and put aside their own wants and needs, thereby undermining user insights (Ananjeva et al., 2020). This was particularly pronounced in the software team.

In Paper 4, we argued that "not having a dedicated budget for UX, clear boundaries, and management, or an open conversation about how to spend money, put everyone working with UX on edge and in vulnerable positions" (Nielsen, Ordoñez, et al., 2023, p. 17). An insufficient UX budget made UX practitioners feel unsupported and unable to perform UX activities effectively, which influenced their motivation to adopt UX. This was reinforced by UX being managed chaotically and haphazardly, based on overhead decision-making, with little 'design management' characterized by compartmentalization, lack of consistency, lack of UX leadership, and representation at strategic levels (Nielsen, Ordoñez, et al., 2023). This resulted in UX practitioners second-guessing their role in both the company and the project, as well as the impact and quality of their work (Nielsen, Ordoñez, et al., 2023).

Prior internal conflicts hindered UX from being a coordinated effort (Nielsen, Ordoñez, et al., 2023). Instead, these conflicts reinforced existing silos and amplified issues practitioners had in aligning UX activities with development and project plans, as well as with other business units. These conflicts made it difficult to secure commitment and support, even from business units facing similar issues with UX-related matters.

5.3.2 UX as a skill set

Transforming a research demonstration, such as a proof-of-concept of a robot, into a practical and profitable product is complex (Norman, 2010). This challenge is compounded by the fact that academic founders of robotics companies often have limited experience with commercializing robots (Dietrich et al., 2021). Industry professionals need to consider product detail, reliability, robustness, sales, profitability, and cost, which are not typically skills that researchers focus on developing (Norman, 2010). My research identified two **barriers** concerning **UX as a skill set** that influenced the adoption of UX:

1. UX is not a prioritized skill in team formation (ado)
2. Confidence of novice UX practitioners is volatile; easily achieved, easily lost (ado)

We observed that UX skills were not prioritized in team formation and project scoping. The timing of including UX specialists in development has been widely debated. Researchers found that involving UX specialists late in design limit their impact (Bang et al., 2017), while others found that UX specialists primarily contribute to upfront design activities (e.g., (Persson et al., 2022; Kuusinen & Väänänen-Vainio-Mattila, 2012)) or report that UX specialists' involvement and role change throughout development (Persson et al., 2018; Kuusinen & Väänänen-Vainio-Mattila, 2012; Bruun et al., 2018). Involving UX specialists in development can also induce power struggles between UX specialists and product owners due to overlapping responsibilities (Kashfi et al., 2019). Additionally, forming specialized UX and Design Thinking teams can lead to reluctance from colleagues to engage and collaborate with such teams, because they see them as threatening established functions and managerial decision-making power (Carlgren, Elmquist, & Rauth, 2016). Considering that robot development is often technology-centered, robotics companies may struggle to involve UX specialists. While R4 collaborated with external UX and UI specialists, these consultants were only tasked with designing screen-based wireframes based on predefined requirements (Paper 3, (Nielsen, Skov, & Bruun, 2023)). They had no authority over design management or the physical design of robots, as this was not part of the contract. This might be because UX in industry predominately targets software-driven products. Thus, when forming robot design teams, robotics companies may not see UX specialists as contributors to the robot's physical design, including attributes in RODECA. Conversely, UX specialists may lack experience collaborating with the diverse group of experts needed for developing robots or knowledge to work beyond screen-based interactions.

Confidence is connected to competence, which is built through training and experience. Suggesting UX activities beyond novice UX practitioners' competence levels resulted in negative reactions because they were pushed too far from their comfort zone (Paper 4, (Nielsen, Ordoñez, et al., 2023)). Colleagues pushing for faster results and implementing untested designs negatively impacted UX competence development, leading to acceptance of poorer quality designs and UX (Nielsen, Ordoñez, et al., 2023). In these cases, established routines resurfaced despite efforts to improve them. Additionally, negative prior experience, such as with workshops providing insufficient results, made practitioners apprehensive about trying new types of workshops. This reluctance may stem from UX practitioners working in a well-established company, which are known to be more risk averse (Ringberg, Reihlen, & Rydén, 2019; Tushman & Nadler, 1986). Conversely, when confidence was accelerated beyond the confidence sweet-spot, it led to tunnel vision and overconfidence (Nielsen, Ordoñez, et al., 2023). This manifested in practitioners not wanting to change the way user studies were conducted and overestimating their own moderator skills while underestimating the value of pilot tests and practice (Nielsen, Ordoñez, et al., 2023).

UX specialists are often asked to create specific design outputs, which limit their effectiveness, influence, and scope of work (Gothelf & Seiden, 2016). Similar applies in robotics. Cila et al. (2024) argued that UX specialists should anticipate and identify authentic users' needs, behaviors, and cognitive abilities, and translate these insights into the design of robots' operating systems, interfaces, forms, configurations, sounds, and movements. This is challenging, as transforming user insights into implementation tasks in robotics is difficult (Lohse et al., 2014; Winkle et al., 2021). My research corroborated these findings, showing that user insights were often ignored or questioned if they did not confirm stakeholders' assumptions. Thus, UX practitioners must delicately balance business needs, stakeholders' assumptions, authentic user needs, and technical feasibility. This requires both hard skills–expert UX knowledge, ability to apply UX methods correctly, make informed trade-offs, interpret data from user studies, and transform such data into actionable design recommendations–and interpersonal skills for communicating and influencing stakeholders to ensure buy-in and support (Rohn, 2007; Nielsen, Ordoñez, et al., 2023). My research emphasizes that UX specialists need hard UX skills to make appropriate trade-offs, interpersonal skills to ensure buy-in, and technical knowledge of how robots are built to progress beyond the screen-based interaction design to effectively influence the mechanical and physical design of the robot.

5.3.3 Coordination of UX

Coordinated UX efforts can promote ownership and shared responsibility among individuals and teams. However, robot development rely on contributions from various disciplines, which present practical coordination challenges for UX integration and adoption. Coordination of UX efforts is linked to design management, which is essential for ensuring a shared product vision and changing organizational cultures that are not conducive to UX. Despite the benefits of establishing a design management paradigm and integrating UX in development, my findings showed this is challenging for robotics companies accustomed to technology-centered development. Coordination is further impacted by different professions having their own theories, methods, tools, and terminology (Šabanović, Michalowski, & Caporael, 2007) and design representations (e.g., artifacts) (Dittmar & Forbig, 2019). These practices must intersect and function within the larger ecosystem of robot development. Coordinating UX efforts and translating and sharing UX outcomes with developers is laborious. This can be traced back to initial project scoped, where managers did not sufficiently consider how practitioners should work with UX. Lack of sufficient consideration for UX in initial project scoping has also been found in other robot development projects (Sandoval et al., 2018). My research identified two **barriers** that influenced **coordination of UX**:

1. Coordination of UX rely on too many people (int)
2. Separation and lack of shared UX responsibility can result in incoherent human-robot interaction (int)

My research demonstrated that coordination of UX in R4 relied on too many people and teams, causing internal confusion, unnecessary complexity, complications, and uncertainty about the direction and integration of UX. Unlike the ideal size and placement of agile teams[1], R4 had more than 40 domain experts and several external partners who were not collocated. Collocating agile teams is highly recommended as it can motive ownership, reduce documentation, and facilitate smoother collaboration (Sharp et al., 2012). Similarly, UX has a larger impact on development decisions if UX specialists and developers work in close physical proximity (Persson et al., 2018). When this is not the case, it increases attention to UI design rather than UX outcomes (Kuusinen, 2015; Nielsen, Ordoñez, et al., 2023). The large team in R4 amplified the need for detailed documentation and limited face-to-face interaction, making it challenging for UX practitioners to share insights that would impact implementation. Coordinating UX and development efforts was difficult and led to confusion because individual teams' development plans did not align with each other or the overall project plan, making it difficult to monitor progress and identify bottlenecks. UX activities, for example, relied on external UX consultants to deliver material (i.e., prototypes and wireframes) for evaluation in user studies, colleagues from other business units or clients to recruit and schedule time with authentic users, negotiating UX scope with another team not involved in the robot development project, and requests from the software team or subject matter experts. This made UX overly complex and time consuming.

My research also showed that the separation and lack of shared UX responsibility can result in incoherent human-robot interaction. Some UX activities were carried out in parallel to development as recommended in (Wale-Kolade et al., 2013; Sy, 2007; Persson et al., 2022, 2018); however, software managers viewed UX as too risky, making it difficult for UX to intersect and impact development. This is because UX was seen as the sole responsibility of product managers rather than a shared responsibility. Buchner et al. (2012) recommended that all stakeholders partake in every step of development to increase attention to UX. Additionally, having the entire team observe user studies can reduce subsequent debriefing activities (Gothelf & Seiden, 2016) and foster empathy and co-ownership (Krout et al., 2020). This is why UX should be a shared responsibility (Kashfi et al., 2017) that is orchestrated and facilitated by UX specialists (Gothelf & Seiden, 2016), who should have the authority to influence project planning if the UX is unsatisfactory (Larusdottir et al., 2017). While involving all

[1]Agile development teams are typically limited to approximately 8-10 collocated people to maintain vigilance and comply with agile principles that stipulate that the most efficient and effective way of communicating is through face-to-face communication and that comprehensive documentation should be avoided (Beck et al., 2001; Sharp, Giuffrida, & Melnik, 2012).

stakeholders may be possible in agile software development teams, it is not feasible in large-scale robot development projects with 40+ domain experts and several external partners who are not collocated. In these situations, robotics companies must coordinate UX to prevent it from being separated from development.

5.3.4 Robot development processes

Robot development is a collaborative and multidisciplinary endeavor, with each discipline bringing distinct development processes, coordination mechanisms, tools, terminology, and design artefacts (Šabanović et al., 2007; Dittmar & Forbig, 2019). Development teams can benefit from integration through mutual adjustment (i.e., adopting practices from other disciplines), but it is important to respect and preserve different practices (Persson et al., 2022). How project managers, team leaders, and individual practitioners respond and adjust to these differences requires room for experimentation, failure, and interdisciplinary curiosity. Navigating and fusing distinct development paradigms is critical in robot development, as robots are complicated and expensive to make (Tulli et al., 2019) and difficult to modify ad-hoc once their physical form is decided and manufactured. My research identified four **barriers** that robot design teams faced due to their distinct **robot development processes**:

1. Mismatch between agile software development and New Product Development (int)
2. Different coordination mechanisms, design artefacts, terminology, and tools (int)
3. Sprint duration does not account for factors impacting physical product development (int)
4. UX is not addressed in development processes used by robot development teams (int)

In Paper 3, we observed that the software team struggled to manage and fuse New Product Development with agile principles (Nielsen, Skov, & Bruun, 2023). This led to **agile fall**, where teams work with fixed scope (requirements defined in upfront activities) and fixed deadlines defined in project kickoff (Gothelf & Seiden, 2016). Despite delays impacting deadline adherence, having a fixed scope and deadlines resulted in less flexibility to pursue new design directions. Another characteristic of **agile fall** we observed was that it forced teams to create comprehensive documentation to support knowledge handover. The mechanical team relied on comprehensive documentation from external stakeholders (clients, technical partners, and suppliers) and produced comprehensive technical drawings and assembly guides for both internal and external use. This was necessary to design the robots' mechanical parts. It may therefore be unrealistic in large-scale robot development to completely avoid comprehensive documentation, as is predicated in the agile manifesto (Beck et al., 2001).

Development teams adhered to distinct development paradigms and utilized different coordination mechanisms, design artefacts, terminology, and tools (Nielsen, Skov, & Bruun, 2023). For example, the mechanical team was unaccustomed to working with user stories (design artefact), whereas the software team was unaccustomed to organizing and facilitating concept and prototype design reviews (coordination mechanism). Only the mechanical team seemed to use roadmaps (coordination mechanism) to track their parallel design tracks, including experiments. Development teams had different understanding of what a 'prototype' was (terminology) and what was expected of each team for the big prototype builds included in the project plan. User stories (design artefact) are commonly used in agile development to represent users (Garcia et al., 2017; Cohn, 2004); however, practitioners had no established process for defining user stories or implementing user insights and struggled to translate these insights into implementation tasks accessible to developers through Jira. This resulted in lack of visibility of user needs, which increased developers' confidence in their own designs and opinions of what users' needed, and raised the risk of developers working from memory (Paper 3, (Nielsen, Ordoñez, et al., 2023)). Robot designers should be aware of these different practices, which are informed by the adopted development paradigm, as they can lead to collaboration and coordination issues.

In Paper 3, we argue that robot development is inherently slow and incremental, characterized by long development cycles, regardless of agile principles (Nielsen, Ordoñez, et al., 2023). A two-week sprint duration does not account for factors impacting physical product development, such as supply chain, material access, and production time. Mechanical development is influenced by these factors, and supply chain issues often caused delays and forced design modifications, which were difficult to plan for. Additionally, UX is not addressed in development processes used by robot development teams. Robot development teams are accustomed to technology-driven development, making it hard for them to integrate and adopt UX without qualified and dedicated support. Consequently, when development teams struggle to fuse New Product Development with agile principles, UX if often overlooked.

5.3.5 Policies for user involvement

Robotics companies must design robots that generate value for authentic users, clients, and even non-users (Bartneck, 2020; Abrams et al., 2021), while considering broader contextual and societal implications (Obaid, Ahtinen, Kaipainen, & Ocnarescu, 2018; Šabanović, 2010; von der Puetten et al., 2020; Jung & Hinds, 2018). Findings from Paper 4 showed that organizational policies dictated user involvement during the robot development process, which often presented barriers beyond the Design team's control (Nielsen, Ordoñez, et al., 2023). Practical factors and corporate policies influence the timing and ways to conduct user studies,regardless of the product. Therefore, companies must identify and manage these potential barriers. My research identified four ways in which **policies for user involvement** posed **barriers** that influenced user involvement in robot development:

1. Access to authentic users and robots (int)
2. Moderating user studies (int)
3. Chunk-testing (int)
4. Requests from stakeholders (int)

Access to authentic users and robots was not guaranteed, which severely influenced the Design team's ability to involve authentic users in the process (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023). Without access to authentic users, developers struggle to empathize with their users (Gothelf & Seiden, 2016; Krout et al., 2020). However, practitioners were only allowed to recruit participants through Gatekeepers (i.e., a specific person, team, or client with direct access to authentic users (Nielsen, Ordoñez, et al., 2023)) or clients, who selected employees as substitutes for authentic users due to strict non-disclosure requirements. Similar issues were reported by Buchner et al. (2012), who found clients reluctant to organize access to authentic users because they did not see the value in doing so. Lack of user involvement led to condescending attitudes towards authentic users–referring to them as simple minded, claiming that they were not proud of their jobs, and that they were at fault and should change if they could not operate the robots–and worries that teams overlooked important user behavior and needs (Nielsen, Skov, & Bruun, 2023). Conversely, involving authentic users and exposing them to the technology promote transparency and ownership of the final robotic system (Carrillo et al., 2018). Limited access to robots restricted UX evaluations to the screen-based interface in meeting rooms (Nielsen, Skov, & Bruun, 2023).

The second policy influencing user involvement pertains to who could moderate user studies (Nielsen, Ordoñez, et al., 2023). This policy required that customer contacting colleagues should moderate sessions with users despite having no experience with moderating formative usability evaluations. While this presented a practical barrier, as the Design team did not moderate the sessions themselves, it also presented an opportunity to promote UX within other business units. This approach complements the matrixing UX resources (Rohn, 2007).

The third policy that influenced user involvement was chunk-testing, where several products were tested in the same session with multiple stakeholders present. Practitioners did not feel that they were in a position to challenge these policies (Nielsen, Ordoñez, et al., 2023).

Lastly, both external and internal stakeholders influenced how user studies were conducted. Internal stakeholders, for example, requested specific questions be asked to participants. To cope with these policies and practical barriers, along with the lack of established UX processes, practitioners often recruited internal colleagues for design evaluations or relied on the expertise of external UX and UI consultants (Paper 3, (Nielsen, Skov, & Bruun, 2023)).

When authentic users are not sufficiently involved in robot design, gaps can arise between how robot designers intend the robot to function and how users actually engage with the robot (Tulli et al., 2019). Lack of authentic user involvement may stem from fears of users asking for an abundance of features, which is costly in robot development (Alves-Oliveira et al., 2022). Consequently, robot designers might treat users as theoretical constructs and design the robot based on untested assumptions. While this can lead to unexpected success because the robot design team coincidentally design for a user not previously considered, it more often results in failure (Alves-Oliveira et al., 2022). My research showed that lack of user involvement is not just due to fear of excessive user demands; it is also a political issue influenced by clients' willingness to provide access to authentic users, decisions regarding who moderates user studies, and requests from stakeholders.

5.3.6 Understanding authentic users

Successful robotics companies design robots for specific purposes with clearly defined tasks (Tulli et al., 2019; Dietrich et al., 2021). This highlights the value of simplicity and designing robots that excel at specific tasks, rather than overloading them with unnecessary features. However, assumptions about user needs often prove incorrect, and user requirements may change during development. While software adjustments can be made post-hoc, this is not as feasible for the robot's physical and mechanical design. Therefore, understanding authentic users' needs is critical for industry robot designers. This understanding is key to integrating social service robots into existing workflows–which links to **contextual integration**–and driving their adoption among primary users and InCoPs. My research identified three **barriers** that influenced industry robot designers' **understanding of authentic users**:

1. Requirements rarely favor authentic user needs (int)
2. Development teams have varying sensitivity to changes in requirements (int)

Identifying authentic user (i.e., daily operators of the robots) requirements enables product teams to develop valuable products for users. However, requirements were often based on outdated and questionable data from customer meetings, historic knowledge, "gut feeling", and second-hand accounts (Paper 3, (Nielsen, Skov, & Bruun, 2023)). User needs were often ignored if they conflicted with organizational decisions or individually held beliefs of what users find important (Paper 4, (Nielsen, Ordoñez, et al., 2023)). For example, practitioners maintained terminology and iconography because it was internally understood, despite user study results confirming that authentic users did not understand it. Product managers also cherry-picked data to support their opinions and created 'user' stories from a 'Product Manager'-perspective to cover features the company wanted to implement (Paper 4, (Nielsen, Ordoñez, et al., 2023)). Similarly, practitioners may invalidate or undermine user stories because they fall in love with the product and not the problem (Ananjeva et al., 2020). User stories were prioritized according to business value, informed by the company's clients or internal stakeholders, and an assessment of required development resources (Paper 3, (Nielsen, Skov, & Bruun, 2023)). Accordingly, when authentic user needs are undermines and ignored, there is a risk that the final product fails to generate value for authentic users (Paper 3, (Nielsen, Skov, & Bruun, 2023)). Furthermore, mechanical design considerations often outweighed authentic users needs due to development efforts. In some cases, it might be financially beneficial to disregard authentic user needs if it requires changes to the physical properties of a product that has already been manufactured (Øvad & Larsen, 2015).

We observed that development teams had varying sensitivity to changes in requirements (Paper 3, (Nielsen, Skov, & Bruun, 2023)). The software team had an ad-hoc approach although preferring that UX requirements remained unchanged. A Change Committee limited UX practitioners' influence on design decisions, as changes required product managers to push for approval from the committee. The 'size' of the change affected acceptance; for instance, the lead software architect stated that changes could only reduce scope, not add features users wanted (Nielsen, Skov, & Bruun, 2023). This rigidity implied that preliminary requirements were considered indisputable by software developers. Conversely, the mechanical team halted development until they confirmed the latest requirements. The benefits of proactively managing requirements[2] were that the mechanical team reduced waste of materials and development time. Variability in teams' response to requirement changes led to inconsistencies in how authentic user needs were addressed and resistance to incorporating changes based on user feedback, which frequently hindered UX integration. This fragmented approach made it difficult to adopt a unified UX strategy, which often led to frustration.

The engineering process behind robots, driven by hardware and software development (Lohse et al., 2014), may explain development teams varying sensitivities to authentic user feedback on requirement changes. Incorporating user insights in robot design is challenging (Winkle et al., 2021; Lohse et al., 2014). My research showed that robot designers struggled to derive pragmatic design issues from user studies and translate them into implementation tasks (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023). There is no guarantee of user acceptance, even if the robot excels at specific tasks. For example, the hospital delivery robot only benefited the primary users, while increasing workload and frustration among other staff, leading to physical and verbal abused of the robot (Mutlu & Forlizzi, 2008). Some companies sold their collaborative robots within a year due to employee resistance (Kadir et al., 2018). These examples highlight the importance of involving authentic users in robot development. HRI theory[3] does not easily translate into practice because it is far removed from real-world deployment of robots (Cila et al., 2024; Stock-Homburg, 2022). While partici-

[2] This issue is addressed further in Section 5.5.7.

[3] Based on Jung and Hinds' (2018) work, Cila et al. (2024, p. 138) define HRI theory as: "[...] theories contribute to a foundational understanding about people as they interact with robots, how specific design choices affect interactions with robots, and how novel mechanisms or computational tools can be used to improve interaction".

patory foregrounds authentic user involvement and provides authentic users with decision making power equal to that of designers and other stakeholders, this is not always the case in HRI or robotics companies. Robot designers might bypass authentic users' needs if they challenge established conventions. For example, despite evidence that a robot did not need a head to communicate, the team added one based on HRI research suggesting users prefer human-like physical features (McGinn et al., 2020). This shows that even with HCD approaches, robot designers may prioritize their assumptions over user insights.

5.3.7 Contextual integration

Contextual integration focuses on how robotics companies account for the physical context that the robots are going to be deployed in. Exploring this context is crucial for seamless integration with existing workflows, as failure to do so can lead to commercial failure (Dietrich et al., 2021). Despite its importance, robot designers often forgo this step and rely on assumptions about human-robot interactions, which rarely hold true (Šabanović, 2010; Šabanović et al., 2014). It is well established that people behave differently around robots compared to other technologies (Chun & Knight, 2020; Forlizzi, 2007). My research identified two **barriers** that industry robot designers encountered regarding **contextual integration**:

1. Context exploration is based on questionable data and second-hand sources (int)
2. Naïve context exploration is unrealistic, as it is expensive and time consuming (int)

In R4, context exploration relied on questionable data and second-hand sources from customer meetings, sales insights, customer support, in-house knowledge, "gut feeling", and personal opinions (Paper 3, (Nielsen, Skov, & Bruun, 2023)). This is problematic for three reasons: the insights might be outdated, unverified by authentic users, and biased due to personal opinions. Combined with the business objectives and customer requirements, this is what R4 relied on when defining the purposes and goals of their robots, as they did not prioritize upfront design activities.

Clients increasingly handle upfront design activities, such as physical context exploration, before hiring a company to develop the product (Persson et al., 2022). This can be problematic as the developing company might lack necessary exposure to the product context and instead rely on requirements that are based on potentially outdated and questionable knowledge. Few companies and researchers can possibly afford naïve physical context exploration. Companies may therefore decide to develop a robot without fully understanding the problem and accept data that validates their direction. This raises the risk that robotics companies attempt to solve a specific contextualized problem with a new robot even if a robot is not the ideal solution. It is understandable that robotics companies are interested in identifying problems and market opportunities for a robot, rather than any other kind of product.

Consequently, users needs are often determined by the company or its clients, rather than by authentic users. For example, a client representative in Paper 4 mentioned that efficiency and return on investment calculations are always made when investing in technologies. Such customer requirements may lead to robots being designed from a robot-led perspective favoring pragmatic qualities such as utility, efficiency, and cost savings, while neglecting nuanced social interactions afforded by robots and diverse users segments.

Accounting for **contextual integration** based on physical context exploration is vital because 1) robot designers' assumptions about human-robot interactions rarely hold true (Šabanović, 2010; Šabanović et al., 2014); 2) many robots are too immature to provide intended services upon market release (Tulli et al., 2019), as seen with KnightScope being retired within months (Rubinstein & Meko, 2024); and 3) people may not be ready to fully accept and interact with robots in public (Thunberg & Ziemke, 2020). Neglecting physical context exploration can lead to serious issues, such as increased workload for non-primary users (Mutlu & Forlizzi, 2008) and deliberate abuse of robots (Brščić, Kidokoro, Suehiro, & Kanda, 2015; Salvini et al., 2010; Mutlu & Forlizzi, 2008; Yamada et al., 2020; Nomura, Kanda, & Yamada, 2015). Additionally, non-compliance with social norms can negatively impact interactions with robots (Karreman, Ludden, & Evers, 2015) and cause personal embarrassment, as users may feel responsible for the robot's actions (Nielsen, Skov, Hansen, & Kaszowska, 2023).

5.4 Implications for the Design of Robot Attributes

The literature highlights that the physical dimension and embodiment of robots add complexity compared to purely software-driven solutions (Yigitbas, Jovanovikj, & Engels, 2021; Alves-Oliveira et al., 2022; Paterson et al., 2023). The identified organizational mechanisms impacted the design of the **Robot Attributes** in RODECA, making detailed work with these attributes challenging in collaboration with R4. My research uncovered three additional **barriers** that influenced the design of **Robot Attributes**:

1. "Robot UX" is treated as "software UX"
2. Deriving pragmatic design issues from user feedback regarding robot attributes
3. Assumptions of the value of human-like qualities are embedded within robot design

While a robot's behavior, appearance, personality traits and attitude, intention markers, interactivity, and its social skills are critical attributes (Fong et al., 2003), practitioners overlooked their importance because they treated "robot UX" as "software UX" (Nielsen, Skov, & Bruun, 2023). This was likely due to poor UX coordination and design management, and the separation of the physical and digital design (Nielsen, Skov, & Bruun, 2023). Practitioners were not trained HRI researchers and were unfamiliar with robot attributes in RODECA and how to, for example, incorporate personality and social awareness into the mechanical design. Senior management and executives, focused on high-level business objectives and return on investment, seemed unaware of the strategic and financial value of designing robots with these attributes in mind. Consequently, robots' unique qualities beyond autonomy and safety systems were not considered in the robot design (Nielsen, Skov, & Bruun, 2023).

The technology-centered robotics companies I collaborated with struggled to account for these attributes. Lack of maturity in this respect prevented them from effectively utilizing insights derived from upfront design activities such as context exploration and user studies conducted during development. Consequently, one of the companies had previously failed to deliver robots that generated value for users and met people's expectations, resulting in loss of customers. Even if pragmatic design issues are derived from user feedback, implementing it in robot design is challenging (Lohse et al., 2014). What makes this difficult in practice is that changes to the robots' aesthetic or changes affecting product price require senior management approval, while changes affecting robots' operational reliability and robustness have to be scrutinized by the mechanical team (Nielsen, Skov, & Bruun, 2023).

Assumptions about the value of human-like qualities (behavior, appearance, personality traits, and social skills) are embedded in robot design. HRI literature generally presumes that robots possessing human-like qualities are preferred by users, increase acceptance, and foster a more positive experience compared to robots without such qualities (Stock-Homburg, 2022; Paetzel-Prüsmann, Perugia, & Castellano, 2021; Eyssel & Kuchenbrandt, 2012), even in industrial contexts (Rahman, 2024; Elprama, Makrini, Vanderborght, & Jacobs, 2016; Chowdhury, Ahtinen, Pieters, & Vaananen, 2020). While supported by empirical evidence, these assumptions are primarily based on controlled experiments with non-authentic users, such as university students (Stock-Homburg, 2022). These assumptions drive robot design in academia and potentially the design of commercial robots (Alves-Oliveira et al., 2022). Research (Nielsen, Jochum, Chrysostomou, Li, & Ordoñez, in review) showed that designing robots based on these assumptions can deter authentic users' acceptance of robots. The main issue is that these assumptions do not account for contextual integration.

5.5 Supporting Robotics Companies to Integrate and Adopt UX

Industry robot designers need research-based guidance on choosing and using relevant and applicable UX techniques and methods (Lindblom & Andreasson, 2016). Researchers must understand practitioners' practices and processes (Buchner et al., 2012; McKay & Marshall, 2001; Stark, 2014; Kidd & Kral, 2005) or experience robot development in a company setting to raise their own contextual sensitivity. While HRI literature provides examples of universal design practices applied in robotics and design frameworks, it lacks focus on understanding the design and development process of commercial social service robots (Sandoval et al., 2018;

Alves-Oliveira et al., 2022) and the underlying mechanisms influencing it. In the introduction, I argued that obtaining such knowledge is crucial for supporting robotics companies in adopting and integrating UX, and is key to filling this knowledge gap.

This section discusses how robotics companies can integrate and adopt UX by examining research findings from the four included papers in relation to literature. First, I briefly address issues with RODECA from Paper 1 (Nielsen et al., 2021), arguing that it may not suit robotics companies with low UX maturity. Then, I return to how robotics companies can be supported in integrating and adopting UX. The discussion is structured around the seven organizational mechanisms: **commitment and support structures**, **UX as a skill set**, **coordination of UX**, **robot development processes**, **policies for user involvement**, **understanding authentic users**, and **contextual integration**. It provides 18 **strategies** which can support robotics companies to **integrate** (int) UX in robot development and **adopt** (ado) UX within the organization, addressing the identified mechanisms:

1. Building a UX-friendly organizational culture in robotics companies
2. Building UX skills in robotics companies
3. Strengthening coordination of UX
4. Merging robot development processes
5. Making the best out of organizational policies for user involvement
6. Handling user requirements and tracking the user's experience
7. Raising contextual sensitivity in robot design teams

Strategies for integration can also positively impact adoption, and vice versa. The strategies in this dissertation draw from the 21 strategies implemented in R4 (Paper 4), the five recommendations from the case study (Paper 3), and the methodological contribution of Paper 2. A total of 18 strategies will be discussed, with 14 implemented (marked as '*implemented*') and four recommended (marked as '*recommended*').

5.5.1 The Robot Design Canvas (RODECA)

The RODECA is an industry-oriented robot design framework that combines HRI literature, the business model canvas (Osterwalder, 2004), and industry robot designers' requirements (Nielsen et al., 2021). However, for robotics companies with low UX maturity, RODECA may not be suitable. It became clear that R4 was not mature enough to work with frameworks such as RODECA, the robot design canvases proposed by Axelsson et al. (2021), or the UX of HRI design methodology proposed by Tonkin et al. (2018). These design frameworks do not account for practitioners working under uncertainty, lack autonomy, and are influenced by managerial decisions that rarely favor UX (Nielsen, Ordoñez, et al., 2023). Conversations with other robotics companies revealed that low UX maturity is a common challenge for robotics companies. This motivated a shift in my research to help bridge the gap between robot development and UX at individual, team, and organizational levels, an issue not sufficiently addressed in HRI research.

Although RODECA was informed by the needs of industry robot designers, my research showed they needed more than a new design framework. Robot designers faced several barriers at individual, team, and organizational levels that hindered UX integration and adoption. They required situated strategies to overcome these barriers.

5.5.2 Building a UX-friendly Organizational Culture in Robotics Companies

Technology-centered and B2B companies commonly favor technology development and functionality over UX (Kashfi et al., 2017), and this tendency may be more pronounced in robotics companies due to the engineering nature of robot development (Lohse et al., 2014). This technology-first focus makes shifting organizational cultures towards UX particularly challenging. However, the 14 *implemented* strategies presented in this discussion contributed to building a more UX-friendly culture in R4. One of these **strategies** contributed strongly to the establishment of **commitment and support structures**:

1. UX practitioners should form alliances with other business units involved in UX-related aspects and motivate co-ownership of UX (ado, *implemented*)

UX integration in robot development and adoption in a robotics company relied on building trust, obtaining commitment, and establishing support structures, which also increased priority of UX. This was achieved by forming alliances with other business units involved in UX-related aspects and motivating co-ownership by involving internal expert stakeholders in formulating usability tasks and training colleagues to moderate usability evaluations (Nielsen, Ordoñez, et al., 2023). Catering to internal stakeholders' needs is crucial for ensuring buy-in and support (Rohn, 2007), which required making trade-offs to win over specific individuals (Nielsen, Ordoñez, et al., 2023).

5.5.3 Building UX Skills in Robotics Companies

Confidence is closely linked to competence, which is built through training and experience. Training developers to take responsibility of some UX activities has been successful in software development (Øvad & Larsen, 2016). While training is essential for competence-building, it alone cannot ensure successful UX integration but serves as a starting point for the transition (Bang et al., 2017; Bornoe & Stage, 2017). I recommend three **strategies** to address barriers influencing **UX as a skill set** in the robotics company:

1. UX specialists establish a safe space for novice UX practitioners to experiment with UX activities (ado, *implemented*)
2. UX specialists scale UX activities according to competence levels, fallback routines, resources, and recent organizational directive in order to maximize impact (ado, *implemented*)
3. The organization offers training programs for growing UX skills (ado, *recommended*)

Establishing a safe space for novice UX practitioners involved insisting on using instructions, conducting pilot tests, and targeted moderator training sessions. The in-house UX designer and I encouraged our novice UX colleagues to share concerns about UX activities, and we adjusted plans accordingly. For example, I facilitated an online co-design workshop when product managers facilitate the online co-design workshop when product managers felt uncomfortable doing so, allowing them to observe an experienced UX specialist (Nielsen, Ordoñez, et al., 2023). Establishing a safe space aligns with Lean UX's promotion of an experimental mindset and permission to fail (Gothelf & Seiden, 2016). The Design team conducted six user-involved activities, a substantial improvement for R4. Permission to fail was delicate, as novice UX practitioners were initially hesitant to conduct user studies without guaranteed valuable insights. Researchers can help establish a safe space, but trust is essential and built through collaboration, for example, afforded by pragmatic research approaches such as longitudinal case studies and action research.

The second successful strategy was scaling UX activities according to novice UX practitioners' competence level by introducing simpler, low-barrier activities like remote, unmoderated usability tests, their fallback routines, and resources and recent organizational directives. Knowing practitioners' UX competence is essential for providing research-based guidance. Our first intervention in the action research collaboration aimed to assess practitioners' competences in real-life action (Nielsen, Ordoñez, et al., 2023). HRI design frameworks are often applied by highly specialized and well-resourced teams (Nielsen et al., 2021), but not all teams work under such conditions. Therefore, HRI researchers must clearly articulate how practitioners can adjust and scale the design framework according to their competences.

I recommend that the organization offers training programs to grow UX skills, as UX specialists should have a broad range of competencies to orchestrate and facilitate UX work (Gothelf & Seiden, 2016) and collaborate across disciplines, while considering technical feasibility, business goals, stakeholders' assumptions, and authentic user needs (Kashfi et al., 2017; Krout et al., 2020; Gothelf & Seiden, 2016). Such competencies, combined with design management capabilities, are essential to open up the design process of robots to practitioners not formally trained in UX. It may be unrealistic to find one UX specialist with all these skills who can also support robot design teams and conduct user studies. Therefore, robotics companies should invest in a dedicated UX team, starting by hiring a senior UX specialist or manager rather than a junior UX designer. In-house UX specialists are not a given in robotics companies, which often necessitates external consultants and researchers to design the UX of robots. While this can risk UX not being integrated within the company (Svanæs & Gulliksen, 2008), it also allows UX and HRI researchers to address real-world issues together with robotics companies. If resources are insufficient for UX training programs or hiring senior UX specialists, managers should establish UX support structures to provide novice UX practitioners with qualified support. In R4, this was achieved by hiring external UX and UI consultants, collaborating with researchers, and involving an internal UX designer. Additionally, organizing meetups for employees working with UX or related fields to share and discuss their work can enhance UX skills and establish internal support structures.

5.5.4 Strengthening coordination of UX

Establishing in-house design management is crucial for ensuring a shared product vision and transforming organizational cultures that do not support coordinated UX efforts. Design management is also vital for effectively supporting multidisciplinary teams in their collaboration and coordination (Carneiro et al., 2021). I recommend three **strategies** which can support robotics companies to strengthen **coordination of UX**:

1. UX practitioners reach internal UX alignment before involving stakeholders (ado, *implemented*)
2. Managers and team leaders (including UX leads) define procedures and formats for translating and sharing UX outcomes (int, *implemented*)
3. UX practitioners develop codebooks, living style guides, and other templates (int, *implemented*)

UX must be a coordinated effort between individuals and teams, regardless of its organizational priority. These three strategies are starting points for coordinating UX, especially in large-scale robot development projects with many stakeholders. Physical distribution posed substantial coordination and collaboration challenges, which required that UX practitioners coordinated and collaborated across vastly different technical teams (Paper 4, (Nielsen, Ordoñez, et al., 2023)). When the responsibility of UX was assigned to practitioners new to UX, developers often dismissed or tried to control UX, leading to poorer quality. Achieving internal UX alignment before involving stakeholders was crucial to present a united front, which made it harder for developers to oppose UX and reduced complexity from too many influences. This alignment was achieved through meetings among internal and external Design team members, discussing challenges (e.g., access to authentic users, sharing insights with developers, convincing managers of design changes) and ways of resolving the challenges in favor of UX. It also involved selective communication of UX outcomes by collaborating with team leaders on implementation plans prior to informing developers of upcoming tasks (Nielsen, Ordoñez, et al., 2023).

Additionally, managers and team leaders (including UX leads) should support UX practitioners in defining procedures and formats for translating and sharing UX outcomes. This is necessary when UX practitioners coordinate and communicate with various distributed teams and stakeholders. Streamlining how UX outcomes are translated and shared can address issues of separation and lack of shared UX responsibility. Findings from Paper 4 indicated that "too many platforms and services were used which impacted easy access to situation-relevant information, collaborative-space, and support systems" (Nielsen, Ordoñez, et al., 2023, p. 15), which often resulted in information being outdated or not reaching the necessary people. Reducing this complexity and increasing visibility of UX outcomes is crucial for industry robot designers. Collaborating with team leaders to establish procedures for communicating UX outcomes in the chosen project management platform (e.g., Jira) is essential, as it "prevented flooding Jira with UX tickets that the R&D team would not be prepared for nor have the resources to deal with" (Nielsen, Ordoñez, et al., 2023, p. 16). While managers and team leaders can initiate the conversation, active participation from both UX practitioners and developers is needed to ensure UX outcomes are communicated effectively for implementation.

When the company lacks a company-wide UX policy, UX efforts risk becoming uncoordinated, leading to duplicate work (Nielsen, Ordoñez, et al., 2023). To prevent this, developing codebooks and living style guides that document visual design decisions, cross-product features, and menu structures is essential. These resources enable easy access to design material, preventing non-compliant designs. However, managing these resources requires effort, which the company did not prioritize despite the product manager's initial codebook for robot design choices. Other templates, such as those for reporting key aspects of user studies (hypotheses, methods, data being collected, participants, findings etc.), can streamline UX activities and reduce overlap. Templates also ensure continuity of information despite employee mobility. Practitioners and I began developing user study templates, but time constraints shifted our focus to implementing viable analysis practices for handling user requirements and tracking UX (explained further in Section 5.5.7).

5.5.5 Merging robot development processes

Robot development is a collaborative and multidisciplinary endeavor, with each discipline contributing distinct processes, coordination mechanisms, tools, terminology, and design artefacts (Šabanović et al., 2007; Dittmar & Forbig, 2019). This diversity can lead to coordination and collaboration challenges (Axelsson et al., 2021; Šabanović et al., 2009) when merging robot development processes. I recommend three **strategies** that can support industry robot design teams in merging **robot development processes** while integrating UX:

1. Project managers and team leaders (including UX leads) align stage-gate transition outputs for each discipline, including UX (int, *recommended*)

2. Project managers, team leaders (including UX leads), and individual practitioners identify and align coordination mechanisms, design artefacts, terminology, and tools (int/ado, *implemented*)

3. Project managers, team leaders (including UX leads), and UX practitioners create a shared roadmap that connects UX to technical deliverables and development activities (int, *implemented*)

Acknowledging that New Product Development (NPD) is more suitable for developing physical, mechanical products like robots than agile development (R. G. Cooper, 2014), it is crucial for project managers and team leaders to align stage-gate transition outputs for each discipline in robot development. These transition outputs were only defined for the technical teams, not UX, making it a *recommended* strategy. Aligning these transition outputs should not limit teams from adopting best practices from their fields, as preserving domain-specific practices is important (Persson et al., 2022). Project managers and team leaders should collaborate to integrate processes and practices that fit their development context while maintaining industry best practices, even if they differ from other development paradigms. In Paper 3, we observed that the mechanical team combined NPD with some agile principles, which enabled them to continuously adapt to changing customer requirements, run parallel design tracks, experiment, and iterate while adhering to the NPD process they were familiar with (Nielsen, Skov, & Bruun, 2023).

The use of different coordination mechanisms, tools, terminology, and design artefacts by development teams can lead to collaboration and coordination issues. Therefore, it is recommend that project managers, team leaders, and individual practitioners identify and align these elements. While it is necessary to respect and preserve domain-specific practices for efficiency (Persson et al., 2022), there should be room to explore which coordination mechanisms, tools, terminology, and design artefacts could benefit other teams and contribute to a more coherent UX. In the case study, the software team established their version of a UX design review, inspired by the mechanical team's design reviews for sharing and evaluating concepts and prototypes, and coordinating subsequent development activities (Nielsen, Skov, & Bruun, 2023). The UX design review clarified UX work for other teams and served as a venue for internal stakeholders to share feedback on UI design and as a gate deliverable (Nielsen, Skov, & Bruun, 2023).

Creating a shared roadmap that connects UX to technical deliverables and development activities integrates and makes visible the *what* (i.e., the functionalities needed to fulfill the user's goal) and *why* (i.e., the interaction value) (Zaina et al., 2021) across teams. This connection reduces the risk of deploying robots that do not generate value for authentic users. The Design team and I began developing a roadmap linking UX deliverables and activities to technical deliverables and development activities of the mechanical and software teams. We faced challenges as UX deliverables depended on these teams and external partners. Technical team leaders prioritized establishing technical feasibility of a customer requirement before designing the interface, which caused delays. Five months later, the product manager and a new software manager reviewed Jira tickets to revise a realistic UX roadmap. Creating such a roadmap is complex in a technology-centered organization new to UX. Despite the effort required, it was necessary to develop a realistic roadmap that would enable UX outcomes to influence design and implementation decisions.

5.5.6 Making the best out of organizational policies for user involvement

UX practitioners felt unable to challenge the organization's policies for user involvement (Nielsen, Ordoñez, et al., 2023). It may therefore be better to accept these policies temporarily to avoid disturbances that could negatively influence UX integration and adoption. Based on my research, I recommend four **strategies** that can help UX practitioners to make the best of the four organizational policies influencing user involvement:

1. Robot design teams use proxies for design evaluations, if access to authentic users is limited (int, *implemented*)
2. UX practitioners collaborate with or outsource recruitment and moderation of user studies to colleagues with customer contact (int, *implemented*)
3. Strategically position stakeholders to observe participants (int, *recommended*)
4. Provide stakeholders with a venue to share feedback (int/ado, *implemented*)

Utilizing proxies in user studies and design evaluations was necessary in R4 due to limited access to authentic user, a strategy also recommend by Sy (2007). Proxies should closely resemble authentic users and have extensive user knowledge; recruiting colleagues without proper consideration is inadvisable. The mechanical team using this strategy considered; a) deliberate and accidental misuse and damage to the robot inflicted by users and InCoPs; b) preventing unauthorized access to machines; and c) making robots easier to operate, maintain, and service (Paper 4, (Nielsen, Ordoñez, et al., 2023)). Risk of minimal user involvement include stereotype propagation, erroneous assumptions about user needs, and overgeneralization and misinterpretation of problems (Alves-Oliveira et al., 2022). My research emphasizes that involving authentic users in intermediary development stages, between initial discovery and final product evaluation, keep design teams aligned with changing user requirements (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023).

Teaming up with or outsourcing participant recruitment and user study moderation to allies, such as Gatekeepers or colleagues with customer contact, facilitated access to authentic users (Nielsen, Ordoñez, et al., 2023). This strategy allowed colleagues with direct customer access to arrange user studies. Implementing this strategy require robot design teams train colleagues to moderate user studies due to internal policy restrictions. Practitioners and I developed training material for moderators, which was shared ahead of a one-hour session discussing the material and the upcoming user study. Conducting user studies with newly trained moderators required two fail-safes: a) having an experienced moderator present to intervene if necessary and b) providing "cheat sheets" with questions and guidance on known wireframe bugs (Nielsen, Ordoñez, et al., 2023).

Practitioners had to accept chunk-testing and the involvement of multiple stakeholders to conduct user studies with authentic users. To address practical barriers arising from this, I recommended that UX practitioners strategically position stakeholders to observe participants and introduce breaks between distinct products being tested, as sessions could last over two hours without breaks. This is an opportunity to have stakeholders observe authentic users interacting with products in order to foster empathy, as recommended in (Gothelf & Seiden, 2016; Krout et al., 2020; Buchner et al., 2012; Nielsen et al., 2021).

To prevent colleagues moderating user studies from deviating and manage stakeholders' influence on user studies, practitioners and I found it beneficial to provide stakeholders a venue to share feedback, ensuring they felt heard before engaging with authentic users (Paper 4, (Nielsen, Ordoñez, et al., 2023)). This was achieved through the co-design workshop and engagement in moderation training. This approach positively impacted UX integration and contributed to the adoption of UX among internal stakeholders and clients involved.

5.5.7 Handling user requirements and tracking the user's experience

The HRI design frameworks in Section 2.1 promote iteration, allowing for some monitoring of the user's experience. For example, Zhong and Schmiedel (2021) resolved usability issues through five cycles of formative usability evaluations of a Pepper robot's interactive behavior. However, simply following an iterative design approach does not guarantee that it is human-centered or addresses authentic users' requirements, as it may rely on feedback from technical experts (Alves-Oliveira et al., 2022) or be informed by HRI research (McGinn et al., 2020) as discussed in Section 5.3.6. Industry robot designers work in a different **situation** than HRI researchers, which influences how they handle user requirements and track user experience. Therefore, I recommend three **strategies** for handling user requirements and tracking user experience to support industry robot designers' **understanding of authentic users**:

1. UX practitioners identify a baseline user experience, e.g., based on formative usability evaluation or competitor analysis (int, *implemented)*

2. Team leaders and UX practitioners proactively assess the legitimacy of requirements, e.g., based on hypothesis testing and inputs from authentic users (int, *implemented*)
3. UX practitioners establish viable analysis practices such that authentic users' needs carry more weight than opinions in design decisions (int/ado, *implemented*)

Digital ethnography can provide empirical insights for defining preliminary user requirements and UX goals for robots without access to authentic users and functioning robots. Practitioners contributing to RODECA argued that robots' goals and success criteria could evolve continuously (Nielsen et al., 2021). I therefore recommend robot design teams identify a baseline user experience through formative usability evaluations (Nielsen, Ordoñez, et al., 2023) or based on an extended competitor analysis using the coding schemes developed in (Nielsen, Skov, Hansen, & Kaszowska, 2023). This approach can help define UX goals for specific user segments, robots, and businesses. Inspiration for UX goals can be drawn from the extended USUS evaluation framework (Wallström & Lindblom, 2020) or other HRI measurement tools. Additionally, applying RODECA (Nielsen et al., 2021) or the 'Problem Space'-, 'Ethical Considerations'-, and 'Environment'-canvases (Axelsson et al., 2021) can help embrace the interconnectedness between physical context, user segments, and the robot's purpose and goals.

In Paper 4, we argue that reactive UX has less impact on development than proactive UX (Nielsen, Ordoñez, et al., 2023). It is critical to proactively assess requirements' legitimacy through hypothesis testing, continuous adjustments, and evaluations with authentic users. Moving UX from reactive to proactive can be achieved by introducing a **sprint 0**, as suggested by Sy (2007), and running parallel design tracks ahead of development sprints. The mechanical team proactively managed development risks by checking in with product managers, confirming requirement changes, and ensuring requirements were met (Paper 3, (Nielsen, Skov, & Bruun, 2023)). They blocked development until they confirmed working on the latest requirements, whereby they reduced waste of materials and development time. Conversely, making UX proactive on the software side was challenging, user study data conflicted with established design decisions, thus questioning user requirements' legitimacy.

To address issues with requirements rarely favoring authentic user needs, the Design team needed to build trust in UX outcomes. This involved eliminating self-participation in user studies, using quotes from authentic users, and ensuring the most recent wireframes were tested to increase trustworthiness in UX outcomes (Nielsen, Ordoñez, et al., 2023). More importantly, novice UX practitioners needed to learn how to analyze qualitative data from user studies, so authentic user needs outweighed colleagues' opinions in design decisions. UX practitioners and I found it beneficial to combine Instant Data Analysis (Kjeldskov et al., 2004) with Gap Analysis principles (IDA-GA) in order to make the analysis more collaborative and allow practitioners to track user experience across design iterations. This helped build arguments based on empirical evidence for design changes, even when conflicting with established decisions. Establishing a viable analysis practice was a crucial step towards proactive UX, supporting the transition from a technology-centered towards a human-centered orientation (Paper 4, (Nielsen, Ordoñez, et al., 2023)).

Regardless of how human-centered an organization is, user needs may conflict with practitioners', managers', or executives' assumptions and business goals. UX practitioners must manage these conflicts by balancing stakeholders' assumptions, business needs, and authentic users' needs. Formulating easily testable hypotheses can support teams to quickly evaluate assumptions about users, products, and business growth, and manage project progress (Krout et al., 2020; Gothelf & Seiden, 2016). Consensus-building techniques like affinity maps, dot voting, and forced ranking can help prioritize content and functionality, but conclusions must be validated with authentic users (Levy, 2021). These aspects are embedded in the second and third strategy. Together with UX practitioners, I developed templates for planning and documenting user studies, including formulating hypothesis. Similarly, the Design team experimented with both dot voting and forced ranking as part of the IDA-GA analysis.

While authentic users should be considered in robot design, it may not always be feasible or financially sensible. Mechanical design considerations can sometimes outweigh authentic users' needs, as mechanical teams must weight development efforts against implementing changes to the mechanical design. In some cases, it might be financially beneficial to disregard authentic users' needs if they require changes to already manufactured products (Øvad & Larsen, 2015). Integrating UX, especially upfront design activities, in mechanical design teams can help prevent scenarios where features are included simply because it is easier and cheaper than manufacturing new parts.

5.5.8 Raising contextual sensitivity in robot design teams

Section 5.3.7 detailed barriers for **contextual integration**. When defining a robot's purpose and goals, they should ideally be grounded in the physical, social context the robot will enter, addressing the needs, pain points, and behaviors of the entire user segment while aligning with business objectives. To address this, I recommend the following **strategy** to raise contextual sensitivity in robot design teams and support industry robot designers in accounting for **contextual integration**, especially when UX resources are limited:

1. UX practitioners supplement competitor analysis and upfront design activities with digital ethnography focusing on the situated interactions people have with robots in the environment(s) they are targeting (int, *recommended*)

Paper 2 presents an application of digital ethnography utilizing user-generated content on YouTube to study unguided interactions with robots in public places and how people overcome interaction breakdowns (Nielsen, Skov, Hansen, & Kaszowska, 2023). Digital ethnography can enhance contextual sensitivity in robot design, enabling market analysis–a requirement industry robot designers had for HRI design frameworks (Nielsen et al., 2021), as discussed in Section 5.1.3–and upfront user research to empathize with the entire user segment. This methodology is particularly relevant for robot design teams lacking resources for extensive physical context exploration and access to authentic users. It allows robot designers to define the robot's purpose and goals based on physical context exploration and user segments. Additionally, digital ethnography provides an alternative channel for incorporating user feedback into agile development, which match the rapid pace of agile development (Larusdottir et al., 2017). Digital ethnology is not a 'quick-and-dirty' version ethnography but aims to support industry needs for more cost-efficient UX (Ardito et al., 2014). Its effectiveness depends on finding quality material, which is easier for social service robots in public places than for surgical robots, where such material is less accessible on social media.

Physical context exploration is critical to robot design, as incorporated into the first two stages (define the challenge and observe) of Tonkin et al.'s (2018) UX for HRI design methodology and the 'Environment'-canvas proposed by Axelsson et al. (2021). Šabanović et al. (2014) demonstrated the value of revisiting the physical context to understand people's routines and behaviors while ideating technological solutions. Physical context exploration is also instrumental in Lean UX (Gothelf & Seiden, 2016) and Design Thinking (Brown, 2019), which typically rely on extensive in-situ explorations. Digital ethnography, as presented in Paper 2, provides an alternative approach for when resources and access are limited.

5.6 Limitations

This dissertation has limitations regarding the transferability of my research. I discuss the the strengths and weaknesses of depth versus breadth in relation to transferability and the potential threat posed by the pragmatic concept of **continuity**. Additionally, I address the implications of the selected case companies and the focus on social service robots. Lastly, I reflect on my own position as a researcher.

5.6.1 Transferability rather than generalizability

One limitation of pragmatic research is that conclusions are informed by what was possible in the given **transactional situation**[4]. This implies that what is possible in one **situation** might also possible in another, but this may not always be the case (Biesta, 2010). According to Morgan, it seems impossible "*[...] for research results to be either so unique that they have no implications whatsoever for other actors in other settings or so generalized that they apply in every pos-*

[4]Recall that **transaction** in pragmatism refers to "*[...] the ongoing and transformative interrelations between the experiencer and his/her circumstances [i.e., the* ***situation****]*" (Dalsgaard, 2008, p. 23).

sible historical and cultural setting" (Morgan, 2007, p. 72). Transferability is therefore relevant for assessing the quality of pragmatic research.

Pragmatism, like action research, is acutely interested in everyday life and resolving local issues (or **conflicts**) when **theory** meets **action** in real-world **situations** (Morgan, 2014a, 2007; Dalsgaard, 2008, 2014; McKay & Marshall, 2001; Kidd & Kral, 2005; Hammersley, 2004; G. R. Hayes, 2011). Case studies share this interest in everyday life and contemporary phenomenon (Yin, 2018; Flyvbjerg, 2006) to study **actions** effectuated by the processes and practices of specific people (Nielsen, Skov, & Bruun, 2023). Critics argue that single case studies and action research lack generalizability and scientific rigor (Flyvbjerg, 2006; McKay & Marshall, 2001)[5]. However, pragmatic and qualitative researchers argue that findings should be assessed by transferability, not generalizability (Hope & Waterman, 2003; Shah & Corley, 2006; G. R. Hayes, 2011; Morgan, 2007). Transferability, along with credibility, dependability, and confirmability, raise research trustworthiness (Shah & Corley, 2006; G. R. Hayes, 2011) as proposed by Lincoln and Guba (1985). As detailed in Table 3.7, transferability is established by providing thick descriptions of the research design, data, analysis, context, and the people being studied, which enable replication and relating findings to other contexts (G. R. Hayes, 2011; Lincoln & Guba, 1985; Shah & Corley, 2006). Transferability is often associated with generalizability, which emphasizes whether research findings are applicable to other situations or people. The following sections discuss the transfereability of my findings, focusing on depth versus breadth and the pragmatic principle of **continuity** as a potential threat to the transferability of findings.

Depth versus breadth

Depth provides a rich, situated understanding of a phenomenon by uncovering underlying mechanisms and their relationships (Yin, 2016). Ensuring depth typically requires extensive, prolonged engagement with participants and reflexive practices. Conversely, **breadth** seeks to gather 'maximum' information from various cases (Yin, 2016). Breadth was prioritized in the first stream of research (**development of the RODECA**), while depth was prioritized for the second stream of research (**understanding how robots are developed**).

Prioritizing **depth** in Papers 3 and 4 enabled me to uncover practitioners' tacit behaviors, unspoken organizational mechanisms, and how the **situation** evolved over time. Opting for breadth would likely have resulted in a surface-level account based on retrospective accounts gathered from interviews, surveys, and archival documents. While multiple case studies may better support claims of generalizability (Ellram, 1996), they lack the depth of a single case

[5]This critique of naturalistic inquiry, such as (digital) ethnography, case study, and action research, concerns all the conventionalist criteria for assessing academic rigor: internal validity, external validity (generlizability), reliability, and objectivity. I choose to focus primarily on transferability instead of generalizability, but the discussion could encompass the other quality criteria as well.

study, especially when it is extreme, critical, common, or longitudinal (Flyvbjerg, 2006; Yin, 2018; Ellram, 1996). The single case study in Paper 3 was a combination of an extreme and longitudinal case, which provided novel insights into how mechanical and software teams embed UX in robot development (Nielsen, Skov, & Bruun, 2023).

Depth is emblematic of action research grounded in pragmatism, as it is a deeply situated, dynamic, and collaborative form of research requiring considerable engagement with practitioners to built trust and resolve immediate, real-world practical and local issues (Kidd & Kral, 2005; McKay & Marshall, 2001; Johansson & Lindhult, 2008). The value of action research lies in producing academic knowledge through dedicated focus on local issues, benefiting all participants through democratic collaboration and personal and professional development (Hope & Waterman, 2003; Hammersley, 2004; McKay & Marshall, 2001; Kidd & Kral, 2005). This value and the impact reported in Paper 4 would not be possible if breadth had been prioritized over depth. Prioritizing depth was necessary to provide detailed accounts of the organizational mechanisms that influenced integration of UX in robot development and adoption of UX in the organization (RQ2) and strategies that supported a robotics company to integrate and adopt UX at individual, team, and organizational levels (RQ3).

Conversely, **breadth** was prioritized in the pilot project (Paper 1), while the digital ethnography (Paper 2) represents both breadth and depth. Breadth is evident from the case selection strategies in Section 3.2.2, which aimed to establish maximum variation in Paper 1 by involving multiple case companies that varied on one or more dimensions, and a purposive sampling strategy led by technology-oriented and case-specific keywords capturing unguided interactions with robots in public places (Paper 2). The decision to prioritize breadth in the pilot project was to capture various perspectives on industry robot designers' needs and concerns regarding HRI design frameworks. Depth was unnecessary at this stage as I was exploring the problem space. Prioritizing breadth was also about capturing multiple perspectives to guide the development of RODECA, which could later be validated in other contexts to demonstrate its transferability and applicability.

The **breadth** in our digital ethnography is reflected in the data collected (104 YouTube videos of varying length) and analyzed using deductive and inductive qualitative content analysis and coded primarily at the semantic level (Nielsen, Skov, Hansen, & Kaszowska, 2023). However, not all digital ethnography relies on breadth; some focus on in-depth accounts. For example, Harley and Fitzpatrick (2009) made an in-depth multimodal interactional analysis of a video blogger and his subscribers. Our digital ethnography also encompassed depth by presenting thick ethnographic descriptions of unguided interactions, similar to other ethnographic studies (Chun & Knight, 2020), as well as case studies and action research. Combining breadth and depth makes these findings transferable to other contexts and potentially generalizable to the larger population. Additionally, the methodology is explained in-depth to facilitate its transferability, which is one of the paper's contributions.

While **breadth** is typically necessary to claim generalizability, this is not the case for transferability in qualitative research. Transferability in qualitative research, as in this dissertation and the included papers, is aided by in-**depth** (or thick) descriptions of the research design, data, context, and participants, as recommended by Lincoln and Guba (1985), regardless of whether findings are based on a single case or multiple cases.

Continuity as a possible threat to transferability of findings

Accepting the pragmatic concept of **continuity**, which acknowledges our ever-changing world (Rylander, 2012), means recognizing that recommendations and strategies presented in research eventually become obsolete. As the world changes, so do the needs of the people we design services, systems, products, technologies, and even frameworks for. While the recommendations and strategies offered in this dissertation and in the included papers may benefit robotics companies and aid the integration of UX in robot development and adoption of UX across robotics organizations, they may not meet future needs. Embracing this limitation suggests that these recommendations and strategies will one day become obsolete, as they are meant to support robotics companies start integrating and adopting UX. In the future, once these practices become routine, new challenges and conflicts will likely emerge, paving the way for expanding this research.

Even so, I do not expect the research findings presented in the four papers and this dissertation to become obsolete soon, as large-scale, industry-wide transformations are inherently difficult and do not happen overnight. Consider the challenges and complexity companies face during digital transformations (Ghosh, Hughes, Hodgkinson, & Hughes, 2022; Björkdahl, 2020). Although companies increasingly embrace the digital agenda, the success rate of such initiatives remains low: less than or about 30% (De la Boutetière, Montagner, & Reich, 2018; Forth, Reichert, de Laubier, & Chakraborty, 2020). Engaging in these digital transformations involves not only new processes, technologies, and technical skills but also developing a conducive organizational environment (Hansen, Larsen, & Lassen, 2021). Similarly, transforming an organization to integrate and adopt UX requires a fundamental shift in practices, which organizations may struggle to create and sustain for various reasons (e.g., lack of understanding, inability or unwillingness to support UX, staff turnover, or leadership changes) (MacDonald, 2019). This is particularly true for companies with longstanding industrial and engineering cultures, such as the case company in Papers 3 and 4, where transition might be difficult due to habitual practices and legacy culture (Liikkanen, 2016).

Until **continuity** threatens the transferability of my findings, I hope this research continues to support robotics companies with in-house development of social service robots. These companies recognize the value of UX, yet struggle to integrate UX in robot development and adopt UX across individual, team, and organizational levels.

5.6.2 Implications of selected case companies

As previously mentioned, this dissertation focuses on robotics companies that value of UX–regardless of what that value might be–yet struggle to integrate UX in their in-house development of social service robots and adopt UX across individual, team, and organizational levels. Consequently, the results may be of limited practical value to robotics companies that already embed UX in development processes and to organizations that purchase and customize existing robot platforms, like NAOs and Peppers, as they likely face different challenges.

The empirical findings in this dissertation might differ if I had collaborated with other robotics companies, as what works in one company may not apply to others (Rosenberg et al., 2015). Company size could have impacted my work, with well-established organizations typically exploring UX less than startups due to being more risk-averse (Mahmoud-Jouini, Fixson, & Boulet, 2019; Ringberg et al., 2019; Tushman & Nadler, 1986). Additionally, UX quality might decline as companies grow, with new team members lacking a UX mentality (Kashfi et al., 2019). Although the internal UX designer and I created a safe space for product managers to experiment with UX and scaled UX activities according to product managers' competence-levels, the organization did not seem to welcome an experimental approach or failure, making novice UX practitioners cautious. Senior management's skepticism of UX, also been found in other established companies (Buchner et al., 2012; Bak, Nguyen, Risgaard, & Stage, 2008), is problematic as they influence company strategies and design decisions. This slowed down UX execution and reduced the impact of authentic users on design decisions, as changes had to pass through many layers within the organization. Researchers and practitioners should be sensitive to the organizational setting and development environment when working with the recommendations and strategies proposed in Papers 3 and 4.

5.6.3 Implications of focusing on social service robots

The focus on physically embodied, social service robots operating in human-populated environments as professional assistive tools for operators (e.g., facility management staff) and as personal service agents for InCoPs might influence the transferability of my results. For example, current legislation may impede or inhibit the design of intuitive and seamless interaction with other types of robots. While there are several safety requirements and protective measures outlined in ISO 13482:2014 (2014) and the European Machinery Directive (2006) concerning the physical, ergonomic, sound, and behavioral design of personal care robots (13482:2014, 2014) and machines in general (Parliament & the Council of the European Union, 2006) which robot designers must comply with, similar does not yet exist explicitly for service robots. These standards can have profound implications for the design of robots' attributes, depending on the the sector and type of robot being developed.

Extending traditional competitor analysis with digital ethnography requires relevant material on social media, which might not available for robots designed for space exploration, surgery, or in industrial settings. Other strategies might be needed to explore the physical context. The importance of the six robot attributes in RODECA (behavior, personality traits and attitude, appearance, interactivity, intention markers, and social skills) depends on the robot application, context, and user segments. Even so, robot designers must decide on these attributes, but the approach and outcome will vary.

5.6.4 Researcher's Position

Section 3.3 described my role as a pragmatic researcher using covert and overt, non-participant and participant observations. Most of my work required substantial and prolonged engagement with practitioners. This section discusses implications of this engagement, considering if the researcher's effect should be controlled for, the researcher's influence during data collection, and the impact pragmatic researchers can have as facilitators of change.

Controlling the effect of the researcher

Pragmatism resolves the debate about whether research is objective or subjective by proposing intersubjectivity, allowing researchers to balance participants' views with those of the research community. Pragmatic researchers typically engage in the phenomenon they study, fostering mutual shaping of experiences rather than controlling for researcher biases. This is especially true in action research, where researchers and practitioners learn from each other to address real-world problems and generate new knowledge (McKay & Marshall, 2001). In our action research, we focused on practitioners' actual behavior and its changes over time, rather than their polished accounts, to understand what hindered quality UX in robot development. Such examination is best achieved through longitudinal participant observations, and I do not consider the researcher's influence in action research as a bias to be avoided. There are situations where it is sensible to control for or avoid the influence of researchers on participants. To investigate truly unguided interactions between people and robots, we opted for covert, non-participant-observation in the digital ethnographic study (Nielsen, Skov, Hansen, & Kaszowska, 2023) to eliminate the risk of researcher influence.

Researcher's influence during data collection

Field observations capture indigenous meaning filtered through the researcher's account of experiences, meanings, and concerns of the observed (Emerson et al., 2011). This means observations are interpreted by the researcher at the moment of creation. My observational notes in both case study and action research meticulously captured practitioners' behavior and speech. To avoid interpretation at creation, I distinguished between my interpretation and factual accounts. This separation was crucial as we did not know what to look for initially and did not want to overlook important details. I maintained a research journal for personal impressions, ideas, and reflections, as recommended by Braun and Clarke (2022). Additionally, UX practitioners agreed to fill out a survey on their UX integration experience after each intervention in the action research (Nielsen, Ordoñez, et al., 2023).

However, we encountered a limitation regarding the detail in observational notes and my developed contextual sensitivity in both the case study and action research. According to Emerson et al. (2011), there are risks with separating what is observed (objectively) from what the researcher captures in their journal (subjectively). First, separation treats data as objective information independent of how it was elicited and by whom. Second, it implies that the researcher's reactions and perceptions should be controlled and separated from the objective accounts to avoid contaminating the data (third) (Emerson et al., 2011). My intention with separating observations from interpretations was not to control my reactions or avoid contamination, but to clarify what was observed and what was interpreted which could help during later analysis, especially involving other researchers. Despite my efforts, my choices on what to emphasize and omit made it difficult for another researcher to apply the coding schemes. This researcher needed background information, which I did not, as my observational notes were sufficient for me to recall events and their connections.

Despite extensive access to practitioners' scrum meetings, the project management tool Jira, some email correspondence, and follow ups with practitioners, I did not participate in meetings with senior management, which could have provided additional insights. The geographical distribution of teams limited my access to the mechanical team and robots. My access was also restricted to the specific project, excluding other projects where UX was relevant.

The researcher as a facilitator of change

When UX integration and adoption are not closely collaborated with industry professionals who will integrate and adopt UX post-research, there is a risk that the research does not impact industry practices, despite practitioners' motivation (Bornoe & Stage, 2017). Therefore, my role in the action research was to orchestrate and facilitate UX integration and adoption, and support UX competence development of robot designers new to UX, to increase the potential of lasting impact. It was also essential for practitioners to be involved and active partners in the transformation, as recommended by Seidelin et al. (2020), to create a more UX-centered robot development process and avoid them becoming passive recipients of UX information, as was found by Zaina et al. (2021).

I supported practitioners in six user-involved activities, including remote formative usability testing and a co-design workshop, which directly contributed to the robots' screen-based interface design and improved UX competences. This impact might not have been possible if I had taken over these activities. Unlike Ardito et al. (2014), my approach focused on supporting industry robot designers integrate and adopt UX practices independently, rather than just demonstrating potential results. This distinction is crucial for generating lasting impact and facilitating growth by raising UX maturity and practitioners' confidence.

5.7 Directions for Further Research

This section proposes four avenues for further research, which can support, extend, or contrast the work presented in this dissertation.

5.7.1 Revisiting the Robot Design Canvas

While the RODECA can contribute to upfront design activities (Cao, 2024), support participatory co-creation by highlighting users' diversity, competence, and autonomy (Greussing et al., 2022), and bridge gaps between robot designers, roboticists, industry, academic researchers, and high schools (Arora, Arora, Sivakumar, & McIntyre, 2023), I envision a future version of RODECA as a catalyst for strategic UX integration and adoption within robotics companies. Ideally, this version would raise UX maturity and practitioners' confidence to apply more elaborate HRI design frameworks. This can be achieved by consolidating findings from the case study and action research collaboration and empirically validating the revised version in other robotics companies.

5.7.2 Extending to other robotics companies

Further research on barriers and strategies for UX integration and adoption in robot development within other robotics companies can provide valuable insights. The barriers and strategies presented in (Nielsen, Ordoñez, et al., 2023) and the above discussion are based on empirical evidence from one well-established robotics company with low UX maturity and no organizational-wide priority for UX. These barriers and strategies may differ in robotics companies with higher UX maturity. Similarly, robotic startups and small- and medium-sized companies may face additional barriers requiring different strategies. Further research is needed to evaluate whether the barriers and strategies in Paper 4 and this dissertation are transferable to robotics companies of varying sizes, UX maturity, and locations, and to identify the drivers of these differences.

5.7.3 Investigating how robot designers work with robot attributes

For practical reasons, I could not explore **Robot Attributes** in detail in R4, leaving this as an open issue for further research. Investigating robots' behavior, appearance, personality traits and attitudes, interactivity, intention markers, and social skills in an industry setting will provide insights into how robotics companies can leverage these qualities to meet authentic user needs. Openness from robotics companies is crucial, and startups might be more receptive to such collaborations, as they may not have established protocols and might be more willing to challenge the status quo by designing robots for multi-user scenarios.

5.7.4 Designing for multi-user scenarios

HRI design frameworks primarily focus on primary users (specific individuals or groups the robot interacts with), while secondary users (e.g., family members and caregivers) are typically considered only when designing robots for healthcare purposes (H. R. Lee et al., 2017; Carrillo et al., 2018). Similarly, software development often designs for primary users despite challenges in accessing authentic users (Kashfi et al., 2017; Ardito et al., 2014). Designing for primary users is more common than for multi-user scenarios, which should encompass the entire network of people directly and indirectly affected by the robot. The digital ethnography highlighted the importance of considering the full spectrum of potential users, including active (primary and secondary) users, inactive (commentators and observers) 'users', and InCoPs (Nielsen, Skov, Hansen, & Kaszowska, 2023). This motivated two robotics startup companies in the pilot project to broaden their scope and consider these dynamic user roles and contextual factors affecting robot interaction and idle behavior. One company initiated design tracks to redesign their robots' intention markers for non-interactive tasks, supported by Interaction Design and Engineering Psychology students I supervised. The other company expanded field study protocols to include the range of people and contextual factors influencing robot behavior. In Paper 3, we observed the mechanical team making design considerations for easier robot maintenance, minimizing abuse and damage to the robot, and preventing unauthorized access, while the software team struggled to consider the primary users due to influences of internal stakeholders' opinions (Nielsen, Skov, & Bruun, 2023).

I strongly recommend that robot designers consider multi-user scenarios, user roles, configurations, and the social dynamics, such as polarization (Martinez et al., 2023). Additionally, I caution against treating 'the user' as a static concept when designing social service robots for public places, as my research shows this is not static. Further research should investigate how HRI design frameworks can explicitly include this perspective to support designing for multi-user scenarios.

6 CONCLUSION

This dissertation investigated how to bridge industry needs and requirements with UX towards the successful development of commercial social service robots. It tackled the issue of balancing business needs, technical development, and UX in robot design. It additionally identified industry robot designers' requirements for HRI design frameworks; presented empirical evidence of organizational mechanisms that influenced UX integration in robot development and adoption in a robotics company; and provided research-based guidance that can support robotics companies to integrate and adopt UX. These are topics that the HRI literature had not hitherto sufficiently addressed. Addressing these research gaps are crucial for providing applicable research-based guidance to industry robot designers integrating UX in robot development, enabling them to improve the UX of their social service robots leading to better commercial performance (Lindblom et al., 2020; Dietrich et al., 2021).

This dissertation applied a pragmatic research approach to bridge these gaps by identifying key requirements that industry robot designers' have for HRI design frameworks, guiding the development of RODECA (Nielsen et al., 2021). Second, it utilized digital ethnography to investigate unguided interactions with social service robots in public places, how people overcome interaction breakdowns, and factors influencing the human-robot interaction (Nielsen, Skov, Hansen, & Kaszowska, 2023). Third, it provided the first longitudinal study of UX integration and adoption in real-world robot development within a commercial setting. The longitudinal, extreme case study provided rich, contextualized insights into how mechanical and software teams embed UX in robot development. This study highlighted the role of UX in robot development, workarounds in design evaluation, requirements handling, and coordination mechanisms (Nielsen, Skov, & Bruun, 2023). The action research with a large, well-established company identified barriers influencing confidence, commitment and support structures, trade-offs in UX, handover practices, UX management paradigm, and trust in UX. It implemented 21 UX strategies to strengthen UX competencies and cultivate corporate UX, providing a detailed examination of how UX integration and adoption work in a real-world commercial setting (Nielsen, Ordoñez, et al., 2023).

Throughout this dissertation, I have demonstrated why researchers must better understand industry robot design in order to bridge HRI theory with practice. This involves strategically integrating UX in robot development and supporting the adoption of UX within robotics companies that see value in UX but struggle to integrate and adopt it across individual, team, and organizational levels. In the following chapter, I conclude this dissertation by answering the research questions that guided my research.

6.1 Answering Research Questions

Based on empirical investigations presented in the four included research papers, I have investigated three research questions.

> **RQ1:** What requirements do industry robot designers have for HRI design frameworks?

Paper 1 identified four requirements industry robot designers have for HRI design frameworks: 1) Provide structure to design and development of robots that solve problems for real people in the actual context; 2) strengthen multidisciplinary collaboration within robot design teams and strengthen engagement with authentic users through a shared language; 3) facilitate market and application exploration; and 4) support competence identification (Nielsen et al., 2021).

First, today's HRI design frameworks meet the requirement of a structured robot design process but do not sufficiently account for development. This makes it challenging for robot design teams to progress beyond prototyping and evaluation of high-fidelity, functional prototypes to implementing outcomes from upfront design activities when developing new commercial robots. Second, some HRI design frameworks (Tonkin et al., 2018; Axelsson et al., 2021; McGinn et al., 2020) and approaches like Participatory Design (H. R. Lee et al., 2017; Nanavati et al., 2023; A. Rogers Wendy et al., 2022; Winkle et al., 2021) are geared to strengthen multidisciplinary collaboration with industry practitioners or support researchers from across disciplines (Šabanović et al., 2009). The literature links the forming of a shared language to avoiding terminology disputes and establishing a shared product vision, rather than dealing with coordinating UX and merging distinct development processes, which my research showed is critical for UX integration and adoption in robotics companies. Third, few HRI design frameworks incorporate stages where commercial applications are identified (Tonkin et al., 2018; Khan & Germak, 2018; McGinn et al., 2020), other technology solutions are considered (McGinn et al., 2020; Axelsson et al., 2021; Šabanović et al., 2014), and benchmarking is established (McGinn et al., 2020; Wallström & Lindblom, 2020). However, systematic examination of what else is on the market to identify a viable business case is not considered. Robotics companies must be able to do this in order to deliver a product that is better than the competition's (R2 and R4) or create an entirely new market (R1). Fourth, identifying the necessary competencies at each stage of robot development is not addressed in today's HRI design frameworks, although researchers report the professional backgrounds of those involved in developing and applying the frameworks.

An important take away from this pilot project and extant literature on HRI design frameworks presented in this dissertation is that today's HRI design frameworks do not sufficiently account for the organizational setting where robot design takes place, despite somewhat addressing three of the four requirements. Thus, it is not that we lack quality HRI design frameworks, but rather that these frameworks seem inapplicable and ill-suited for the industry settings in which practitioners work. In this dissertation, I argued that these frameworks are either too generic or too abstract for seamless integration with robot development paradigms followed by robotics companies and presume ideal scenarios regarding the resources, competencies, commitment, and support of UX.

> **RQ2:** How do organizational mechanisms influence UX integration in robot development and adoption in robotics companies?

Based on Paper 3 (the case study (Nielsen, Skov, & Bruun, 2023)) and Paper 4 (the action research (Nielsen, Ordoñez, et al., 2023)), I identified seven organizational mechanism that influenced UX integration in robot development and adoption in robotics companies. These mechanisms were organized into foundational elements (**commitment and support structures** and **UX as a skill set**), operational aspects (**coordination of UX** and **robot development processes**), user-focused aspects (**policies for user involvement** and **understanding authentic users**), and **contextual integration**. Linked to these mechanisms, my research identified 14 barriers primarily influencing UX integration in robot development and seven barriers primarily influencing the adoption of UX in a robotics company.

The adoption of UX was influenced by two mechanisms linked to **foundational aspects**. First, the **commitment and support structures** (Nielsen, Ordoñez, et al., 2023) for UX adoption were influenced by several barriers. Although UX received verbal support, this did not translate into practice. Managers' often skeptical views of UX were transmitted to their teams, and the trustworthiness and priority given to UX outcomes depended on whether participants in user studies were authentic users or expert stakeholders, with the latter carrying more weight. Additionally, the UX budget was insufficient and spread thinly across teams, and internal conflicts hindered UX from becoming a coordinated effort among individuals and teams. Second, the adoption of **UX as a skill set** (Nielsen, Ordoñez, et al., 2023) was influenced by the fact that UX was not a prioritized skill in team formation. This led to the assignment of UX responsibilities to practitioners new to the field, resulting in the confidence of novice UX practitioners being volatile; it was easily achieved and easily lost.

The integration of UX was influenced by mechanisms linked to operational aspects, user-focused aspects, and contextual integration. First, the **operational aspects** related to **coordination of UX** and **robot development processes** influenced UX integration in the various ways. **Coordination of UX** (Nielsen, Ordoñez, et al., 2023) relied on too many people, causing internal confusion, unnecessary complexity, complications, and uncertainty about the direction and integration of UX. This, combined with managers' viewing UX as too risky, made it difficult for UX to intersect and impact development, reinforcing separation and lack of shared UX responsibility, resulting in incoherent human-robot interaction. Practitioners faced several challenges when merging **robot development processes** (Nielsen, Skov, & Bruun, 2023) due to mismatches between agile software development and New Product Development paradigms. This mismatch was evident in the various coordination mechanisms, design artefacts, terminology, and tools that distinct teams depended on for their work. One issue was that the typical two-week sprint duration did not account for factors impacting physical product development, such as supply chain issues, material availability, and mechanical design. These challenges often led industry robot designers to overlook UX.

Second, the **user-focused aspects** linked to **policies for user involvement** and **understanding authentic users** influenced UX integration in robot development. Organizational **policies for user involvement** (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023) dictated who and when authentic users (i.e., operators) could participate in user studies, as access to operators and robots was not guaranteed and had to be provided by Gatekeepers and clients. This severely influenced the Design team's ability to involve operators in the process (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023). A second policy required customer-contacting colleagues to moderate sessions with operators despite having no experience with moderating formative usability evaluations. Chunk-testing several products in the same session with multiple stakeholders present and stakeholders requesting specific questions to be asked to participants influenced how user studies were conducted. UX practitioners did not feel in position to challenge these policies. **Understanding authentic users** (Nielsen, Skov, & Bruun, 2023; Nielsen, Ordoñez, et al., 2023) is fundamental to UX, as it enables product teams to develop valuable products for users. However, requirements were often based on outdated and questionable data from customer meetings, historic knowledge, "gut feeling", and second-hand accounts (Nielsen, Skov, & Bruun, 2023). Operators' needs were often ignored or modified if they conflicted with organizational decisions or individually held beliefs of what operators find important (Nielsen, Ordoñez, et al., 2023). Development teams had varying sensitivity to changes in user requirements (Nielsen, Skov, & Bruun, 2023). The software team had an ad-hoc approach despite preferring that UX requirements remained unchanged, whereas the mechanical team proactively managed requirements, ensuring that they worked on the latest requirements. Variability in teams' sensitivity and response to requirement changes led to inconsistencies in how authentic user needs were addressed and resistance to incorporating changes based on user feedback, which frequently influenced UX integration. This fragmented approach made it difficult to adopt a unified UX strategy, which often led to frustration.

Third, **contextual integration** focuses on how robotics companies account for the physical context in which the robots will be deployed in. Similar to user requirements, context exploration was often based on questionable data and second-hand sources. This is problematic for three reasons: the insights might be outdated, unverified by authentic users, and biased due to personal opinions. Combined with the business objectives and customer requirements, this is what the large, well-established company relied on when defining the purposes and goals of their robots, as they did not prioritize allocating sufficient resources to naïve context exploration.

In summary, a total of 21 barriers were identified across the case study and action research and discussed in Section 5.3. These barriers were mapped onto the seven organizational mechanisms influencing the integration of UX in robot development and the adoption of UX in robotics companies. Despite being mapped onto specific organizational mechanisms, each barrier had implications for other mechanisms. For example, if UX is not a prioritized skill in the formation of robot design teams, then **commitment and support structures** suffer as colleagues question the quality of UX outcomes and view UX as being dispensable. Consequently, the **coordination of UX** will often be haphazard and inadequate. This will also impact **contextual integration**, which is characterized by questionable data, second-hand sources, and assumptions about authentic users and driven by high-level business objectives and clients who favor efficiency and return on investment. These organizational mechanisms and their relationship underscore the importance of considering both **integration** and **adoption** of UX for social service robots. HRI researchers need to account for both aspects in HRI design frameworks while improving and clarifying the applicability of these frameworks, enabling industry robot designers to fuse them with their practices.

Based on my research, this dissertation identified 14 integration barriers and seven adoption barriers, showing that segmentation is built into the structure of robotics companies and manifest in how they integrate and adopt UX. As a result of experiencing these barriers, UX practitioners reverted to old ways of carrying out UX and relied on historic data from outdated user studies. These barriers made UX progress seem unclear and made UX activities appear uncoordinated (Nielsen, Skov, & Bruun, 2023). In Paper 4, we observed that distributed teams were counterproductive to establishing a sustainable, cross-organizational UX management paradigm. When too many people exerted influence over UX, it increased complexity and resulted in a lack of shared product vision (Nielsen, Ordoñez, et al., 2023). In these situations, UX practitioners frequently made compromises that favored internal stakeholders at the expense on satisfying and identifying authentic user needs.

RQ3: How can robotics companies be supported to integrate and adopt UX?

Paper 1 proposes RODECA (Nielsen et al., 2021), an industry-oriented robot design framework that aims to bridge the gap between industry robot designers' needs, business perspectives, technical development, and UX. However, for robotics companies with low UX maturity or where practitioners work under uncertainty, lack autonomy, and are influenced by managerial decisions that rarely favor UX (Nielsen, Ordoñez, et al., 2023), frameworks like RODECA may not be suitable.

Paper 2 proposes digital ethnography (Nielsen, Skov, Hansen, & Kaszowska, 2023) as a cost-efficient methodology that can extend traditional competitor analysis, facilitate market and application exploration, support robotics companies in integrating UX insights into robot development, and raise contextual sensitivity in industry robot design teams. This methodology is particularly suitable for robot design teams lacking resources for extensive physical context exploration and access to authentic users. It allows robot designers to define the robot's purpose and goals based on context exploration and user segments. Additionally, digital ethnography can provide an alternative channel for incorporating user feedback into agile development, as it can match the rapid pace of agile development. Its effectiveness depends on finding quality material, which is easier for social service robots in public places than for surgical robots, where such material is less accessible on social media.

The best way my research supports robotics companies in integrating and adopting UX is through the situated, pragmatic approach that relied on the case study and action research to provide solutions to localized problems. To integrate and adopt UX effectively, my research proposes that robotics companies establish **commitment and support structures** and **UX as a skill set** as the foundational elements, as they provide the necessary base for **coordinating UX** and **merging robot development processes**. With these operational aspects in place, robotics companies can focus on **user involvement** and **understanding authentic users**. Finally, addressing **contextual integration** ensures robots are designed for their social environments. To support robotics companies, a total of 18 strategies (14 of which were implemented in a robotics company) were identified across the papers and discussed in this dissertation.

UX integration in robot development and adoption of UX in a robotics company required mutual adjustment and tailored initiatives at individual, team, and organizational levels. These levels were identified in the case study (Nielsen, Skov, & Bruun, 2023), which primarily considered the team level, and the action research (Nielsen, Ordoñez, et al., 2023), which addressed all three levels. Initiatives should be made at the individual level by working closely with practitioners responsible for a robot's UX in order to raise practitioners' competencies and confidence levels, as **building UX skills in robotics companies** influenced the adoption of UX across the three levels. At the individual level, this was accomplished by establishing a safe space for novice UX practitioners to experiment with UX activities and scaling UX activities according to competence levels, fallback routines, resources, and recent organizational directives to maximize impact (Nielsen, Ordoñez, et al., 2023). Integrating UX at the team level required that project managers and team leaders (including UX leads) aligned stage-gate transition outputs for each discipline, including UX; identified and aligned coordination mechanisms, design artefacts, terminology, and tools; and created a shared roadmap that connected UX to technical deliverables and development activities for **merging robot development processes** (Nielsen, Skov, & Bruun, 2023). Integration and adoption of UX at the organizational level required that practitioners formed cross-organizational alliances and coordinated UX efforts. and Additionally, the organization offer training programs for growing UX skills, establish a company-wide UX policy to minimize risks of UX becoming uncoordinated and leading to duplicate work (Nielsen, Ordoñez, et al., 2023), and loosen organizational policies that negatively impact how user studies are conducted, such as chunk-testing and access to operators. Doing so contributes to building a more UX-friendly organizational culture.

My dissertation makes substantial inroads into the important conversation of UX in robotics and addresses the contemporary issue of opening up the design of robots to practitioners from robotics companies not formally trained in UX. To facilitate this, my dissertation offers contextualized and evidence-based strategies aimed at supporting individual industry robot designers, robot design teams, and robotics companies in integrating and adopting UX. By collaborating closely with robotics companies and industry practitioners, this dissertation takes an important step towards bridging HRI theory and practice, as considered by Cila et al. (2024), and explicitly addresses the call for action to collaborate with industry robot designers to bring about change, as emphasized by Buchner et al. (2012), Lindblom and Andreasson (2016), and Wallström and Lindblom (2020). While context might trump content, the strategies presented in this dissertation can support UX integration and adoption in robotics companies, particularly those with low UX maturity. My research not only addressed research gaps, it also had practical value. According to the product managers with whom I have collaborated:

> "the most substantial impact these interventions have made is that they have de-risked the design process and provided ways to work with UX under conditions of uncertainty" (Nielsen, Ordoñez, et al., 2023, p. 23).

REFERENCES

13482:2014, I. (2014). *Robots and robotic devices – safety requirements for personal care robots* (Standard). Geneva, Switzerland: International Organization for Standardization (ISO).

8373:2021, I. (2021). *Robotics vocabulary* (Standard). Geneva, Switzerland: International Organization for Standardization (ISO).

9241-210:2019, I. (2019). *Ergonomics of human-system interaction - part 210: Human-centred design for interactive systems (iso 9241-210:2019)* (Standard). Geneva, Switzerland: International Organization for Standardization (ISO).

Abrams, A. M. H., Dautzenberg, P. S. C., Jakobowsky, C., Ladwig, S., & von der Pütten, A. M. R. (2021). A theoretical and empirical reflection on technology acceptance models for autonomous delivery robots. In *Proceedings of the 2021 acm/ieee international conference on human-robot interaction* (pp. 272–280). New York, NY, USA: Association for Computing Machinery. doi: https://doi.org/10.1145/3434073.3444662

Alenljung, B., Lindblom, J., Andreasson, R., & Ziemke, T. (2017). User experience in social human-robot interaction. In *International journal of ambient computing and intelligence (ijaci)* (Vol. 8 (2), pp. 12–31). IGI Global. doi: 10.4018/IJACI.2017040102

Alves-Oliveira, P., Arriaga, P., Paiva, A., & Hoffman, G. (2021). Children as robot designers. In *Proceedings of the 2021 acm/ieee international conference on human-robot interaction* (pp. 399–408). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3434073.3444650

Alves-Oliveira, P., Orr, A., Björling, E. A., & Cakmak, M. (2022). Connecting the dots of social robot design from interviews with robot creators. In *Frontiers in robotics and ai* (Vol. 9, pp. 1–15). frontiers. doi: 10.3389/frobt.2022.720799

Ananjeva, A., Persson, J. S., & Bruun, A. (2020). Integrating ux work with agile development through user stories: An action research study in a small software company. In *The journal of systems & software* (Vol. 170). Elsevier Inc. doi: 10.1016/j.jss.2020.110785

Anthony, L., Kim, Y., & Findlater, L. (2013). Analyzing user-generated youtube videos to understand touchscreen use by people with motor impairments. In *Chi '13: Proceedings of the sigchi conference on human factors in computing systems* (pp. 1223–1232). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2470654.24661584

Ardito, C., Buono, P., Caivano, C., Costabile, M. F., & Lanzilotti, R. (2014). Investigating and promoting ux practices in industry: An experimental study. In E. L.-C. Law & S. Abrahão (Eds.), *Journal of human-computer studies* (Vol. 72 (6), pp. 542–551). doi: 10.1016/j.ijhcs.2013.10.004

Arora, A. S., Arora, A., Sivakumar, K., & McIntyre, J. R. (2023). Robotic interventions for learning (rob-i-learn): Examining social robotics for learning disabilities through business model canvas. In *Companion of the 2023 acm/ieee international conference on human-robot interaction* (pp. 277–281). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3568294.3580088

Axelsson, M., Oliceira, R., Racca, M., & Kyrki, V. (2021). Social robot co-design canvases: A participatory design framework. In *Acm transactions on human-robot interaction* (Vol. 11 (1), pp. 3–39). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3472225

Azenkot, S., Feng, C., & Cakmak, M. (2016). Enabling building service robots to guide blind people - a participatory design approach. In *2016 11th acm/ieee international conference on human-robot interaction (hri)* (pp. 3–10). Christchurch, New Zealand: IEEE. doi: 10.1109/HRI.2016.7451727

Bak, J. O., Nguyen, K., Risgaard, P., & Stage, J. (2008). Obstacles to usability evaluation in practice: A survey of software development organizations. In *Nordichi '08: Proceedings of the 5th nordic conference on human-computer interaction: building bridges* (pp. 23–32). Lund, Sweden: Association for Computing Machinery. doi: 10.1145/1463160.1463164

Bang, K., Kanstrup, M. A., Kjems, A., & Stage, J. (2017). Adoption of ux evaluation in practice: An action research study in a software organization. In R. Bernhaupt, G. Dalvi, A. Joshi, D. K. Balkrishan, J. O'Neill, & M. Winckler (Eds.), *16th ifip tc 13 international conference on human-computer interaction, interact 2017* (Vol. 10516, pp. 169–188). Springer, Cham. doi: 10.1007/978-3-319-68059-0_11

Bartneck, C. (2020, October). *Why do all social robots fail in the market?* Retrieved from `https://www.human-robot-interaction.org/2020/10/19/why-do-all-social-robots-fail-in-the-market/`

Bartneck, C., Belpaeime, T., Eyssel, F., Kanda, T., Keijsers, M., & Šabanović, S. (2020). *Human-robot interaction - an introduction.* Cambridge University Press. Retrieved from `https://www.human-robot-interaction.org`

Bartneck, C., & Forlizzi, J. (2004). A design-centred framework for social human-robot interaction. In *Ro-man 2004. 13th ieee international workshop on robot and human interactive communication (ieee catalog no.04th8759)* (pp. 591–594). IEEE. doi: 10.1109/ROMAN.2004.1374827

Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. In *International journal of social robotics* (pp. 71–81). Springer. doi: 10.1007/s12369-008-0001-3

Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., … Thomas, D. (2001). *Manifesto for agile software development.* Retrieved from `https://agilemanifesto.org`

Biesta, G. (2010). *Pragmatism and the philosophical foundations of mixed methods research* (Second ed.; A. Tashakkori & C. Teddlie, Eds.). SAGE Publications, Inc. doi: 10.4135/

9781506335193

Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: A tool to enhance trustworthiness or merely a nod to validation? In *Qualitative health research* (Vol. 26 (13), pp. 1802–1811). doi: 10.1177/1049732316654870

Björkdahl, J. (2020). Strategies for digitalization in manufacturing firms. In *California management review* (Vol. 62 (4), pp. 17–36). SAGE Publications. doi: 10.1177/0008125620920349

Blessing, L. T. M., & Chakrabarti, A. (2009). *Drm, a design research methodology*. London, UK: Springer.

Blythe, M., & Cairns, P. (2009). Critical methods and user generated content: the iphone on youtube. In *Chi '09: Proceedings of the sigchi conference on human factors in computing systems* (pp. 1467–1476). Boston, MA, USA. doi: 10.1145/1518701.1518923

Blythe, M., & Cairns, P. (2010). Tenori-on stage: Youtube as performance space. In *Proceedings of the 6th nordic conference on human-computer interaction: Extending boundaries* (pp. 72–81). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1868914.1868927

Bornoe, N., & Stage, J. (2017). Active involvement of software developers in usability engineering: Two small-scale case studies. In R. Bernhaupt, G. Dalvi, A. Joshi, D. K. Balkrishan, J. O'Neill, & M. Winckler (Eds.), *16th ifip tc 13 international conference on human-computer interaction, interact 2017* (Vol. 10516, pp. 159–168). Springer, Cham. doi: 10.1007/978-3-319-68059-0_10

Braun, V., & Clarke, V. (2022). *Thematic analysis - a practical guide*. London, UK: SAGE Publications Ltd.

Breazeal, C. (2003). Toward sociable robots. In *Robotics and autonomous systems* (Vol. 42 (3 - 4), pp. 167–175). Elsevier Science. doi: 10.1016/S0921-8890(02)00373-1

Broadbent, E., Montgomery Walsh, R., Martini, N., Loveys, K., & Sutherland, C. (2020). Evaluating the usability of new software for medication management on a social robot. In *Companion of the 2020 acm/ieee international conference on human-robot interaction* (pp. 151–153). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3371382.3378320

Brown, T. (2008). Design thinking: Thinking like a designer can transform the way you develop products, services, processes - and even strategy. In (pp. 85–92). Harvard Business Review. Retrieved from `https://hbr.org/2008/06/design-thinking`

Brown, T. (2019). *Change by design - how design thinking transforms organizations and inspires innovation.* 195 Broadway, New York, NY 10007: Harper Business.

Bruun, A., Larusdottir, M. K., Nielsen, L., Nielsen, P. A., & Persson, J. S. (2018). The role of ux professionals in agile development: A case study from industry. In *Nordichi '18: Proceedings of the 10th nordic conference on human-computer interaction* (pp. 352–363). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3240167.3240213

Brščić, D., Kidokoro, H., Suehiro, Y., & Kanda, T. (2015). Escaping from children's abuse of social robots. In *Proceedings of the tenth annual acm/ieee international conference on human-robot interaction* (pp. 59–66). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2696454.2696468

Buchner, R., Mirnig, N., Weiss, A., & Tscheligi, M. (2012). Evaluating in real life robotic environment: Bringing together research and practice. In *2012 ieee ro-man: The 21st ieee international symposium on robot and human interactive communication* (pp. 602–607). Paris, France: IEEE. doi: 10.1109/ROMAN.2012.6343817

Cao, J. (2024). How robot comes into our life in urban public space: A participatory study. In *Companion of the 2024 acm/ieee international conference on human-robot interaction* (pp. 292–296). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3610978.3640638

Carlgren, L., Elmquist, M., & Rauth, I. (2016). The challenges of using design thinking in industry - experiences from five large firms. In *Creativity and innovation management* (Vol. 25 (3), pp. 344–362). John Wiley & Sons Ltd. doi: 10.1111/caim.12176

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing design thinking: The concept in idea and enactment. In *Creativity and innovation management* (Vol. 25 (1), pp. 38–57). John Wiley & Sons Ltd. doi: 10.1111/caim.12153

Carneiro, V., da Rocha, A. B., Rangel, B., & Alves, J. L. (2021). Design management and the sme product development process: A bibliometric analysis and review. In *The journal of design, economics, and innovation* (Vol. 7 (2), pp. 197–222). Elsevier. doi: 10.1016/j.sheji.2021.03.001

Carpinella, C. M., Wyman, A. B., Perez, M. A., & Stroessner, S. J. (2017). The robotic social attributes scale (rosas): Development and validation. In *Proceedings of the 2017 acm/ieee international conference on human-robot interaction* (pp. 254–262). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2909824.3020208

Carrillo, F. M., Butchart, J., Knight, S., Scheinberg, A., Wise, L., Sterling, L., & McCarthy, C. (2018). Adapting a general-purpose social robot for paediatric rehabilitation through in situ design. In *Acm transactions on human-robot interaction* (Vol. 7 (1), pp. 1–30). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3203304

Chiva, R., & Alegre, J. (2007). Linking design management skills and design function organization: An empiricical study of spanish and italian ceramic tile producers. In *Journal of technovation* (Vol. 27, pp. 616–627). Elsevier. doi: 10.1016/j.technovation.2007.05.015

Cho, J. Y., & Lee, E.-H. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. In *The qualitative report* (Vol. 19 (32), pp. 1–20). Fort Lauderdale: Nova Southeastern University, Inc. doi: 10.46743/2160-3715/2014.1028

Chowdhury, A., Ahtinen, A., Pieters, R., & Vaananen, K. (2020). User experience goals for designing industrial human-cobot collaboration: A case study of franka panda robot.

In *Proceedings of the 11th nordic conference on human-computer interaction: Shaping experiences, shaping society* (pp. 1–13). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3419249.3420161

Chun, B., & Knight, H. (2020). The robot makers: An ethnography of anthropomorphism at a robotics company. In *Journal of human-robot interaction* (Vol. 9 (3)). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3377343

Cila, N., González González, I., Jacobs, J., & Rozendaal, M. (2024). Bridging hri theory and practice: Design guidelines for robot communication in dairy farming. In *Proceedings of the 2024 acm/ieee international conference on human-robot interaction* (pp. 137–146). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3610977.3634991

Cohn, M. (2004). *User stories applied: For agile software development* (First ed.). 75 Arlington Street, Suite 300, Boston, MA 02116, USA: Pearson Education, Inc.

Colusso, L., Bennett, C. L., Hsieh, G., & Munson, S. A. (2017). Translational resources: Reducing the gap between academic research and hci practice. In *Proceedings of the 2017 conference on designing interactive systems* (pp. 957–968). New York, NY, USA: Association for Computing Machinery. Retrieved from `https://doi.org/10.1145/3064663.3064667` doi: 10.1145/3064663.3064667

Commission, E. (2018). *Eu data protection rules.* Retrieved from `https://ec.europa.eu/info/law/law-topic/data-protection/eu-data-protection-rules_en`

Cooper, R., Junginger, S., & Lockwood, T. (2009). Design thinking and design management: A research and practice perspective. In *Design management review* (Vol. 20 (2), pp. 46–55). Wiley. doi: 10.1111/j.1948-7169.2009.00007.x

Cooper, R. G. (1988). The new product process: A decision guide for management. In *Journal of marketing management* (Vol. 3 (3), pp. 238–255). Taylor & Francis Group, LLC. doi: 10.1080/0267257X.1988.9964044

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. In *Business horizons* (Vol. 33 (3), pp. 44–54). Elsevier.

Cooper, R. G. (2014). What's next?: After stage-gate - progressive companies are developing a new generation of idea-to launch processes. In *Research-technology management* (Vol. 57 (1), pp. 20–31). Taylor & Francis. doi: 10.5437/08956308X5606963

Corrales-Paredes, A., Sanz, D. O., Terrón-López, M.-J., & Egido-García, V. (2023). User experience design for social robots: A case study in integrating embodiment. In *Sensors* (Vol. 23 (11), pp. 1–19). MDPI. doi: 10.3390/s23115274

Dalsgaard, P. (2008). Designing for inquisitive use. In *Proceedings of the 7th acm conference on designing interactive systems* (pp. 21–30). New York, NY, USA: Association for Computing Machinery. Retrieved from `https://doi.org/10.1145/1394445.1394448` doi: 10.1145/1394445.1394448

Dalsgaard, P. (2014). Pragmatism and design thinking. In *International journal of design* (Vol. 8 (1), pp. 143–155).

Da Silva, T. S., Silveira, M. S., Maurer, F., & Silveira, F. F. (2018). The evolution of agile uxd. In *Journal of information and software technology* (Vol. 102, pp. 1–5). Elsevier. doi: 10.1016/j.infsof.2018.04.008

de Graaf, M. M. A., & Allouch, S. B. (2013). Exploring influecing variables for the acceptance of social robots. In *Journal of robotics and autonomous systsems* (Vol. 61, pp. 1476–1486). Elsevier. doi: 10.1016/j.robot.2013.07.007

De la Boutetière, H., Montagner, A., & Reich, A. (2018). *Unlocking success in digtial transformation.* Retrieved from https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/unlocking-success-in-digital-transformations#/

Dietrich, J., Dance, J., & Tolson, M. (2021). *Why robotics companies fail* (White Paper). Retrieved from https://www.freshconsulting.com/insights/white-papers/why-robotics-companies-fail/

Dittmar, A., & Forbig, P. (2019). Integrating personas and use case models. In D. Lamas, F. Loizides, L. Nacke, H. Petrie, M. Winckler, & P. Zaphiris (Eds.), *Human-computer interaction – interact 2019* (Vol. 11746, pp. 666–686). Springer, Cham. doi: 10.1007/978-3-030-29381-9_4

Dixon, B., Eklund, A. R., & Wegener, F. (2023). Introduction: Pragmatism, dewey, and design inquiry. In *Design issues* (Vol. 39 (4), pp. 3–8). Massachusetts Institute of Technology. doi: 10.1162/desi_e_00733

Eklund, A. R., Aguiar, U. N., & Amacker, A. (2021). Design thinking as sensemaking–developing a pragmatist theory of practice to (re)introduce sensibility. In *Journal of product innovation management* (pp. 1–20). Wiley Online Library. doi: 10.1111/jpim.12604

Ellram, L. M. (1996). The use of the case study method in logistic research. In *Journal of business logistics* (Vol. 17 (2), pp. 93–138).

Elprama, S. A., Makrini, I. E., Vanderborght, B., & Jacobs, A. (2016). Acceptance of collaborative robots by factory workers: a pilot study on the importance of social cues of anthropomorphic robots. In *The 25th ieee international symposium on robot and human interactive communication (ro-man 2016).* New York, NY, USA: IEEE.

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (2011). *Writing ethnographic fieldnotes* (Second ed.). The University of Chicago Press.

Eyssel, F., & Kuchenbrandt, D. (2012). Social categorization of social robots: Anthropomorphism as a function of robot group membership. In *British journal of social psychology* (Vol. 51 (4), pp. 724–731). Wiley. doi: 10.1111/j.2044-8309.2011.02082.x

Fedosov, A., Boos, D., Schmidt-Rauch, S., jarno Ojala, & Lewkowicz, M. (2021). Challenges of transferring ux designs and insights across products and services. In *Proceedings of the 19th european conference on computer-supported cooperative work: The international venue on practice-centred computing on the design of cooperation technologies - exploratory* *papers, reports of the european society for socially embedded technologies.* doi: 10.18420/ecscw2021-wsmc05

Feilzer, M. Y. (2010). Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. In *Journal of mixed methods research* (Vol. 4 (1), pp. 6–16). SAGE. doi: 10.1177/1558689809349691

Ferreira, J., Sharp, H., & Robinson, H. (2011). User experience design and agile development: managing cooperation through articulaation work. In *Journal of software - practice and experience* (Vol. 41, pp. 963–974). John Wiley & Sons, Ltd. doi: 10.1002/spe.1012

Ferreira, J., Sharp, H., & Robinson, H. (2012). Agile development and user experience design integration as on ongoing achievement in practice. In *Agile conference* (pp. 11–20). IEEE. doi: 10.1109/Agile.2012.33

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. In *Qualitative inquiry* (Vol. 12 (2), pp. 219–245). Sage Publications. doi: 10.1177/1077800405284363

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. In *Journal of robotics and autonomous systems* (Vol. 42, pp. 143–166). Elsevier. doi: 10.1016/S0921-8890(02)00372-X

Forlizzi, J. (2007). How robotic products become social products: An ethnographic study of cleaning in the home. In *Proceedings of the acm/ieee international conference on human-robot interaction* (pp. 129–136). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1228716.1228734

Forth, P., Reichert, T., de Laubier, R., & Chakraborty, S. (2020). *Flipping the odds of digital transformation success.* Retrieved from `https://www.bcg.com/publications/2020/increasing-odds-of-success-in-digital-transformation`

Fox, D., Sillito, J., & Maurer, F. (2008). Agile methods and user-centered design: How these two methodologies are being successfully integrated in industry. In *Agile conference* (pp. 63–72). IEEE. doi: 10.1109/Agile.2008.78

Frederiks, A. D., Octavia, J. R., Vandevelde, C., & Saldien, J. (2019). Towards participatory design of social robots. In D. Lamas, F. Loizides, L. Nacke, H. Petrie, M. Winckler, & P. Zaphiris (Eds.), *Human-computer interaction – interact 2019. interact 2019. lecture notes in computer science* (Vol. 11747, pp. 527–535). Springer, Cham. doi: 10.1007/978-3-030-29384-0_32

Garcia, A., da Silva, T. S., & Silveira, M. S. (2017). Artifacts for agile user-centered design: A systematic mapping. In *Proceedings of the 50th hawaii international conference on system sciences* (pp. 5859–5868). doi: http://hdl.handle.net/10125/41870

Garcia, A., da Silva, T. S., & Silveira, M. S. (2019). Artifact-facilitated communication in agile user-centered design. In P. Kruchten, S. Fraser, & F. Coallier (Eds.), *Agile processes in software engineering and extreme programming. xp 2019* (Vol. 355, pp. 102–118). Springer, Cham. doi: 10.1007/978-3-030-19034-7_7

Geertz, C. (1973). Thick description: Toward an interpretive theory of culture. In *The* *interpretation of cultures* (pp. 310–323). Basic Books, Inc.

Ghazali, A. S., Ham, J., Barakova, E., & Markopoulos, P. (2020). Persuasive robots acceptance model (pram): Roles of social responses within the acceptance model of persuasive robots. In *International journal of social robotics* (Vol. 12, pp. 1075–1092). Springer. doi: 10.1007/s12369-019-00611-1

Ghosh, S., Hughes, M., Hodgkinson, I., & Hughes, P. (2022). Digital transformation of industrial businesses: A dynamic capability approach. In *Technovation* (Vol. 113, pp. 1–18). Elsevier Ltd. doi: 10.1016/j.technovation.2021.102414

Glaser, B. G., & Strauss, L., Anselm. (1967). *The discovery of grounded theory - strategies for qualitative research.* 35 Berrue Circle, Piscataway, New Jersey, USA: AldineTransaction.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. In *European journal of information systems* (Vol. 21 (2), pp. 135–146). Taylor & Francis. doi: 10.1057/ejis.2011.54

Goodman, E., Stolterman, E., & Wakkary, R. (2011). Understanding interaction design practices. In *Proceedings of the sigchi conference on human factors in computing systems* (pp. 1061–1070). New York, NY, USA: Association for Computing Machinery. Retrieved from `https://doi.org/10.1145/1978942.1979100` doi: 10.1145/1978942.1979100

Gothelf, J., & Seiden, J. (2016). *Lean ux - designing great products with agile teams* (Second ed.). 1005 Gravenstein Highway North, Sebastopol, CA, USA: O'Reilly Media, Inc.

Gray, C. M., Stolterman, E., & Siegel, M. A. (2014). Reprioritizing the relationship between hci research and practice: bubble-up and trickle-down effects. In *Proceedings of the 2014 conference on designing interactive systems* (pp. 725–734). New York, NY, USA: Association for Computing Machinery. Retrieved from `https://doi.org/10.1145/2598510.2598595` doi: 10.1145/2598510.2598595

Gray, C. M., Toombs, A. L., & Gross, S. (2015). Flow of competence in ux design practice. In *Proceedings of the 33rd annual acm conference on human factors in computing systems* (pp. 3285–3294). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2702123.2702579

Greussing, E., Gaiser, F., Klein, S. H., Straßmann, C., Ischen, C., Eimler, S., … Utz, S. (2022). Researching interactions between humans and machines: methodological challenges. In *Publizistik* (Vol. 67, pp. 531–554). Springer. doi: 10.1007/s11616-022-00759-3

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. In *Eric/ectj annual review paper* (Vol. 29 (2), pp. 75–91).

Guba, E. G., & Lincoln, Y. S. (1994). *Competing paradigms in qualitative research* (N. K. Denzin & Y. S. Lincoln, Eds.). Thousand Oaks: SAGE Publications, Inc.

Guest, G., MacQueen, K. M., & Namey, E. E. (2014). Applied thematic analysis. In (pp. 21–48). Thousand Oaks: SAGE Publications, Inc. doi: 10.4135/9781483384436

Hammersley, M. (2004). Action research: a contradiction in terms? In *Oxford review of education* (Vol. 30 (2), pp. 165–181). Taylor & Francis Group. doi: 10.1080/

0305498042000215502

Hansen, A. K., Larsen, M. S. S., & Lassen, A. H. (2021). The role of absorptive capacity & employee empowerment in digital transformation of smes. In *Proceedings of the conference on learning factories (clf) 2021* (p. 6). SSRN. doi: 10.2139/ssrn.3859277

Harley, D., & Fitzpatrick, G. (2009). Creating a conversational context through video blogging: A case study of geriatric1927. In *Journal of computer in human behavior* (Vol. 25 (3), pp. 679–689). Elsevier. doi: 10.1016/j.chb.2008.08.011

Hassenzahl, M. (2010). *Experience design: Technology for all the right reasons*. Morgan & Claypool. doi: 10.2200/S00261ED1V01Y201003HCI008

Hassenzahl, M., & Tractinsky, N. (2006). User experience - a research agenda. In *Behaviour & information technology* (Vol. 25 (2), pp. 91–97). Taylor & Francis. doi: 10.1080/01449290500330331

Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard relibabilty measure for coding data. In *Communication methods and measures* (Vol. 1 (1), pp. 77–89). Routledge, Taylor & Francis Group. doi: 10.1080/19312450709336664

Hayes, G. R. (2011). The relationship of action research to human-computer interaction. In *Acm trans. comput.-hum. interact* (Vol. 18 (3), p. 20). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1993060.1993065

Hoffman, G., & Ju, W. (2014). Designing robots with movement in mind. In *Journal of human-robot interaction* (Vol. 3 (1), pp. 91–122). Journal of Human-Robot Interaction Steering Committee. doi: https://doi.org/10.5898/JHRI.3.1.Hoffman

Holthaus, P., Schulz, T., Lakatos, G., & Soma, R. (2023). Communicative robot signals: Presenting a new typology for human-robot interaction. In *Proceedings of the 2023 acm/ieee international conference on human-robot interaction* (pp. 132–141). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3568162.3578631

Hope, K. W., & Waterman, H. A. (2003). Praiseworthy pragmatism? validity and action research. In *Journal of advanced nursing* (Vol. 44 (2), pp. 120–127). Blackwell Publishing Ltd. doi: 10.1046/j.1365-2648.2003.02777.x

Horstmann, A. C., & Krämer, N. C. (2019). Great expectations? relation of previous experiences with social robots in real life or in the media and expectancies based on qualitative and quantitative assessment. In *Frontiers in psychology* (Vol. 10, pp. 1–14). Frontiers. doi: 10.3389/fpsyg.2019.00939

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. In *Qualitative health research* (Vol. 15 (9), pp. 1277–1288). Sage Publications. doi: 10.1177/1049732305276687

Jacobs, A., Elprama, S. A., & Jewell, C. I. (2020). Evaluating human-robot interaction with ethnography. In C. Jost et al. (Eds.), *Human-robot interaction - evaluation methods and their standardization* (Vol. 12, pp. 269–286). Springer Nature Switzerland. doi: 10.1007/978-3-030-42307-0_11

Jewitt, C. (2012). An introduction to using video for research. In *Ncrm working paper.* NCRM (Unpublished). Retrieved from `http://eprints.ncrm.ac.uk/2259/`

Joffe, H., & Yardley, L. (2004). *Content and thematic analysis* (First ed.; D. F. Marks & L. Yardley, Eds.). SAGE Publications, Inc. doi: 10.4135/9781849209793

Johansson, A. W., & Lindhult, E. (2008). Emancipation or workability? critical versus pragmatic scientific orientation in action research. In *Journal of action research* (Vol. 6 (1), pp. 95–115). SAGE Publications. doi: 10.1177/1476750307083713

Jung, M., & Hinds, P. (2018). Robots in the wild: A time for more robust theories of human-robot interaction. In *Journal of human-robot interaction* (Vol. 7). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3208975

Kadir, B. A., Broberg, O., & Souza da Conceição, C. (2018). Designing human-robot collaborations in industry 4.0: Explorative case studies. In D. Marjanović, M. Štorga, S. Škec, N. Bojčetić, & N. Pavković (Eds.), *Ds 92: Proceedings of the design 2018 15th international design conference* (pp. 601–610). The Design Society. doi: 10.21278/idc.2018.0319

Karreman, D., Ludden, G., & Evers, V. (2015). Visiting cultural heritage with a tour guide robot: A user evaluation study in-the-wild. In A. Tapus, E. André, J.-C. Martin, F. Ferland, & M. Ammi (Eds.), *Social robotics. icsr 2015. lecture notes in computer science* (Vol. 9388, pp. 317–326). Springer, Cham. doi: /10.1007/978-3-319-25554-5_32

Kashfi, P., Feldt, R., & Nilsson, A. (2019). Integrating ux principles and practices into software development organizations: A case study of influencing events. In *The journal of systems and software* (Vol. 154, pp. 37–58). Elsevier. doi: 10.1016/j.jss.2019.03.066

Kashfi, P., Nilsson, A., & Feldt, R. (2017). Integrating user experience practices into software development processes: implications of the ux characteristics. In J. Procter (Ed.), (Vol. 3:e130, pp. 1–40). PeerJ Computer Science. doi: 10.7717/peerj-cs.130

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. In *Journal of social sciences* (Vol. 8 (9), pp. 1–17). MDPI. doi: 10.3390/socsci8090255

Kelly, L. M., & Cordeiro, M. (2020). Three principles of pragmatism for research on organizational processes. In *Journal of methodological innovations* (Vol. 13 (2), pp. 1–10). SAGE. doi: 10.1177/2059799120937242

Khan, S., & Germak, C. (2018). Reframing hri design opportunities for social robots: Lessons learnt from a service robotics case study approach using ux for hri. In *Future internet* (Vol. 10 (10), pp. 1–22). mdpi. doi: 10.3390/fi10100101

Kidd, S. A., & Kral, M. J. (2005). Practicing participatory action research. In *Journal of counseling psychology* (Vol. 52 (2), pp. 187–195). 750 First Street, NE, Washington, DC 20002-4242: American Psychological Association. doi: 10.1037/0022-0167.52.2.187

Kjeldskov, J., Skov, M. B., & Stage, J. (2004). Instant data analysis: Conducting usability evaluations in a day. In *Proceedings of the third nordic conference on human-computer interaction* (pp. 233–240). New York, NY, USA: Association for Computing Machinery.

doi: 10.1145/1028014.1028050

Komkaite, A., Lavrinovica, L., Vraka, M., & Skov, M. B. (2019). Underneath the skin: An analysis of youtube videos to understand insertable device interaction. In *Proceedings of chi '19: Chi conference on human factors in computing systems (chi '19).* New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3290605.3300444

Krout, K., Carrascal, J. P., & Lowdermilk, T. (2020). Lean ux research at scale: a case study. In *Proceedings of mensch und computer 2020* (pp. 53–59). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3404983.3405587

Kuusinen, K. (2015). Task allocation between ux specialists and developers in agile software development projects. In J. Abascal, S. Barbose, M. Fetter, T. Gross, P. Palanque, & M. Winckler (Eds.), *15th ifip tc 13 international conference on human-computer interaction, interact 2015* (Vol. 9298, pp. 27–44). Springer, Cham. doi: 10.1007/978-3-319-22698-9_3

Kuusinen, K., & Väänänen-Vainio-Mattila, K. (2012). How to make agile ux work more efficient: management and sales perspectives. In *Proceedings of the 7th nordic conference on human-computer interaction: Making sense through design* (pp. 139–148). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2399016.2399037

Larusdottir, M., Gulliksen, J., & Cajander, (2017). A license to kill - improving ucsd in agile development. In *Journal of systems and software* (Vol. 123, pp. 214–222). Elsevier. doi: 10.1016/j.jss.2016.01.024

Law, E. L.-C., & Lárusdóttir, M. K. (2015). Whose experience do we care about? analysis of the fitness of scrum and kanban to user experience. In *International journal of human-computer interaction* (Vol. 31, pp. 584–602). Taylor & Francis Group, LLC. doi: 10.1080/10447318.2015.1065693

Lee, H. R., Šabanović, S., Chang, W.-L., Nagata, S., Piatt, J., Bennett, C., & Hakken, D. (2017). Steps toward participatory design of social robots: Mutual learning with older adults with depression. In *Proceedings of the 2017 acm/ieee international conference on human-robot interaction* (pp. 244–253). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2909824.3020237

Lee, M. K., Kiesler, S., Forlizzi, J., Srinivasa, S., & Rybski, P. (2010). Gracefully mitigating breakdowns in robotic services. In *Proceedings of the 5th acm/ieee international conference on human-robot interaction* (pp. 203–210). Osaka, Japan: IEEE Press. doi: 10.5555/1734454.1734544

Levy, J. (2021). *Ux strategy: Product strategy techniques for devising innovative digital solutions* (2nd ed.). 1005 Gravenstein Highway North, Sebastopol, CA: O'Reilly Media, Inc.

Li, C., Chrysostomou, D., Pinto, D., Hansen, A. K., Bøgh, S., & Madsen, O. (2022). Hey max, can you help me? an intuitive virtual assistant for industrial robots. In *Journal of applied sciences* (Vol. 13 (1), pp. 1–18). MDPI. doi: 10.3390/app13010205

Liikkanen, L. A. (2016). Ux strategy as a kick-starter for design transformation in an engineering company. In *Proceedings of the 2016 chi conference extended abstracts on human factors in computing systems* (pp. 816–822). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2851581.2851590

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, California, USA: SAGE Publications, Inc.

Lindblom, J., Alenljung, B., & Billing, E. (2020). Evaluating the user experience of human-robot interaction. In C. Jost et al. (Eds.), *Human-robot interaction - evaluation methods and their standardization* (Vol. 12, pp. 231–256). Switzerland: Springer Nature. doi: 10.1007/978-3-030-42307-0_9

Lindblom, J., & Andreasson, R. (2016). Current challenges for ux evaluation of human-robot interaction. In C. Schlick & S. Trzcieliński (Eds.), *Advances in ergonomics of manufacturing: Managing the enterprise of the future* (Vol. 490, pp. 267–277). Springer, Cham. doi: 10.1007/978-3-319-41697-7_24

Lindland, K. M. F. (2022). Re-framing design and designers: Studying design processes through a pragmatic lens. In *Drs.* Design Research Society. doi: 10.21606/drs.2022.567

Liu, B., Tetteroo, D., & Markopoulos, P. (2023). 3 key challenges in designing advanced social robotic applications. In *2023 32nd ieee international conference on robot and human interactive communication (ro-man)* (pp. 1004–1011). IEEE. doi: 10.1109/RO-MAN57019.2023.10309623

Lohse, M., Siepmann, F., & Wachsmuth, S. (2014). A modeling framework for user-driven iterative design of autonomous systems. In *International journal of social robot* (Vol. 6, pp. 121–139). Springer. doi: 10.1007/s12369-013-0209-8

Lupetti, M. L., Zaga, C., & Cila, N. (2021). Designerly ways of knowing in hri: Broadening the scope of design-oriented hri through the concept of intermediate-level knowledge. In *Proceedings of the 2021 acm/ieee international conference on human-robot interaction* (pp. 389–398). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3434073.3444668

MacDonald, C. M. (2019). User experience (ux) capacity-building: A conceptual model and research agenda. In *Proceedings of the 2019 on designing interactive systems conference* (pp. 187–200). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3322276.3322346

Magistretti, S., Bianchi, M., Calabretta, G., Candi, M., Dell'Era, C., Stigliani, I., & Verganti, R. (2022). Framing the mulitfaceted nature of design thinking in addressing different innovation purposes. In *Long range planning* (Vol. 55 (5), p. 14). Elsevier. doi: 10.1016/j.lrp.2021.102163

Mahdi, H., Akgun, S. A., Saleh, S., & Dautenhahn, K. (2022). A survey on the design and evolution of social robots – past, present and future. In *Journal of robotics and autonomous systems* (Vol. 156, pp. 1–48). Elsevier. doi: 10.1016/j.robot.2022.104193

Mahmoud-Jouini, S. B., Fixson, S. K., & Boulet, D. (2019). Making design thinking work -

adapting an innovative approach to fit a large technology-driven firm. In *Research-technology management* (Vol. 62 (5), pp. 50–58). Taylor & Francis. doi: 10.1080/08956308.2019.1638485

Martinez, J. E., VanLeeuwen, D., Stringam, B. B., & Fraune, M. R. (2023). Hey?! what did you think about that robot? groups polarize users' acceptance and trust of food delivery robots. In *Proceedings of the 2023 acm/ieee international conference on human-robot interaction* (pp. 417–427). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3568162.3576984

McGinn, C., Bourke, E., Murtagh, A., Donovan, C., Lynch, P., Cullinan, M. F., & Kelly, K. (2020). Meet stevie: a socially assistive robot developed through application of a 'design thinking' approach. In *Journal of intelligent & robotic systems* (Vol. 98, pp. 39–58). Springer, Nature. doi: 10.1007/s10846-019-01051-9

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. In *Biochemia medica* (Vol. 22 (3), pp. 276–282). doi: 10.11613/BM.2012.031

McKay, J., & Marshall, P. (2001). The dual imperatives of action research. In *Information technology and people* (Vol. 14 (1), pp. 46–59). doi: 10.1108/09593840110384771

Morgan, D. L. (2007). Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods. In *Journal of mixed methods research* (Vol. 1 (1), pp. 48–76). SAGE Publications, Inc. doi: 10.1177/2345678906292462

Morgan, D. L. (2014a). *Integrating qualitative and quantitative methods: A pragmatic approach*. SAGE Publications, Inc. doi: 10.4135/9781544304533

Morgan, D. L. (2014b). Pragmatism as a paradigm for social research. In *Journal of qualitative inquiry* (Vol. 20 (8), pp. 1045–1053). SAGE. doi: 10.1177/1077800413513733

Moshkina, L., Endo, Y., & Arkin, R. C. (2006). Usability evaluation of an automated mission repair mechanism for mobile robot mission specification. In *Proceedings of the 1st acm sigchi/sigart conference on human-robot interaction* (pp. 57–63). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1121241.1121253

Mott, T., Bejarano, A., & Williams, T. (2022). Robot co-design can help us engage child stakeholders in ethical reflection. In *Proceedings of the 2022 acm/ieee international conference on human-robot interaction* (pp. 14–23). IEEE. doi: 10.5555/3523760.3523767

Mutlu, B., & Forlizzi, J. (2008). Robots in organizations: The role of workflow, social, and environmental factors in human-robot interaction. In *Hri '08: Proceedings of the 3rd acm/ieee international conference on human robot interaction* (pp. 287–294). New York, NY, USA: Association for Computing Machinery. Retrieved from `http://doi.acm.org/10.1145/1349822.1349860` doi: 10.1145/1349822.1349860

Nanavati, A., Alves-Oliveira, P., Schrenk, T., Gordon, E. K., Cakmak, M., & Srinivasa, S. S. (2023). Design principles for robot-assisted feeding in social contexts. In *Proceedings of the 2023 acm/ieee international conference on human-robot interaction* (pp. 24–33). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3568162.3576988

Nielsen, S., Jochum, E., Chrysostomou, D., Li, C., & Ordoñez, R. (in review). 'robot emotions are not real!': Future factory workers' perception, attitudes, and experience of ai-empowered collaborative robots and virtual assistants. In *Journal of human-robot interaction.*

Nielsen, S., Ordoñez, R., Hansen, K. D., Skov, M. B., & Jochum, E. (2021). Rodeca: A canvas for designing robots. In *Companion of the 2021 acm/ieee international conference on human-robot interaction* (pp. 266–270). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3434074.3447173

Nielsen, S., Ordoñez, R., Skov, M. B., & Jochum, E. (2023). Strategies for strengthening ux competencies and cultivating corporate ux in a large organization developing robots. In *Journal of behaviour & information technology.* Taylor & Francis Group. doi: 10.1080/0144929X.2023.2227284

Nielsen, S., Skov, M. B., & Bruun, A. (2023). User experience in large-scale robot development: A case study of mechanical and software teams. In *Human-computer interaction - interact 2023* (Vol. 14143, pp. 40–61). Springer, Cham. doi: 10.1007/978-3-031-42283-6_3

Nielsen, S., Skov, M. B., Hansen, K. D., & Kaszowska, A. (2023). Using user-generated youtube videos to understand unguided interactions with robots in public places. In *Journal of human-robot interaction* (Vol. 12 (1), p. 40). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3550280

Nomura, T., Kanda, T., & Yamada, S. (2015). Why do children abuse robots? In *Proceedings of the tenth annual acm/ieee international conference on human-robot interaction extended abstracts* (pp. 63–64). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2701973.2701977

Nomura, T., Suzuki, T., Kanda, T., & Kato, K. (2006). Altered attitudes of people towards robots: Investigation through the negative attitudes toward robots scale. American Association for Artificial Intelligence.

Norman, D. A. (2010). The research-practice gap: The need for translational developers. In *Interactions* (Vol. 17, pp. 9–12). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1806491.1806494

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. In *International journal of qualitative methods* (Vol. 16, pp. 1–13). Los Angeles, CA: SAGE Publications. doi: 10.1177/1609406917733847

Obaid, M., Ahtinen, A., Kaipainen, K., & Ocnarescu, I. (2018). Designing for experiences with socially interactive robots. In *Proceedings of the 10th nordic conference on human-computer interaction* (pp. 948–951). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3240167.3240257

Obaid, M., Baykal, G. E., Kırlangıc, G., Göksun, T., & Yantaç, A. E. (2024). Collective co-design activities with children for designing classroom robots. In *Proceedings of the*

4th african human computer interaction conference (pp. 229–237). New York, NY, USA: Association for Computing Machinery. doi: 10.5555/3523760.3523767

O'Connor, C., & Joffe, H. (2020). Intercoder reliability in qualitative research: Debates and practical guidelines. In *International journal of qualitative methods* (Vol. 19, pp. 1–13). Los Angeles, CA: SAGE Publications. doi: 10.1177/1609406919899220

Osterwalder, A. (2004). *The business model ontology - a proposition in a design science approach* (Unpublished doctoral dissertation). Universite de Lausanne.

Paay, J., Kjeldskov, J., & Skov, M. B. (2015). Connecting in the kitchen: An empirical study of physical interactions while cooking together at home. In *Cscw '15: Proceedings of the 18th acm conference on computer supported cooperative work social computing* (pp. 276–287). Vancouver, BC, Canada. doi: 10.1145/2675133.2675194

Paetzel-Prüsmann, M., Perugia, G., & Castellano, G. (2021). The influence of robot personality on the development of uncanny feelings. In *Computers in human behavior* (Vol. 120, pp. 1–17). Elsiver Ltd. doi: 10.1016/j.chb.2021.106756

Parliament, E., & the Council of the European Union. (2006, May). *Directive 2006/42/ec of the european parliament and of the council of 17 may 2006 on machinery, and amending directive 95/16/ec (recast) (text with eea relevance)* (Directive). European Union. Retrieved from `http://data.europa.eu/eli/dir/2006/42/oj`

Paterson, M., Hoffman, G., & Zheng, C. Y. (2023). Introduction to the special issue on 'designing the robot body: Critical perspectives on affective embodied interaction'. In *Transactions on human-robot interaction* (pp. 1–9). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3594713

Pedersen, J. H. H., Sørensen, M., Stage, J., & Høegh, R. T. (2021). Introducing asynchronous remote usability testing in practice: An action research project. In C. Ardito et al. (Eds.), *Human-computer interaction – interact 2021. interact 2021. lecture notes in computer science* (Vol. 12935, pp. 320–338). Springer, Cham. doi: 10.1007/978-3-030-85610-6_19

Pernice, K., Gibbons, S., Moran, K., & Whitenton, K. (2021, Jun). *The 6 levels of ux maturity.* Retrieved from `https://www.nngroup.com/articles/ux-maturity-model/`

Persson, J. S., Bruun, A., Lárusdóttir, M. K., & Nielsen, P. A. (2022). Agile software development and ux design: A case study of integration by mutual adjustment. In *Journal of information and software technology* (Vol. 152). Elsevier. doi: 10.1016/j.infsof.2022.107059

Persson, J. S., Nielsen, P. A., & Bruun, A. (2018). Agility for ux and development - a case study. In *Nordichi '18: Proceedings of the 10th nordic conference on human-computer interaction.* New York, NY, USA: Association for Computing Machinery.

Pimminger, S., Kurschl, W., Schönböck, J., Slabihoud, R., Froschauer, R., & Zwettler, G. A. (2024). Towards a user-centered design approach for the development of social assistive robots in office environments. In *Proceedings of the 17th international conference on pervasive technologies related to assistive environments* (pp. 45–54). New York, NY, USA: Association for Computing Machinery. Retrieved from `https://doi.org/`

10.1145/3652037.3652073 doi: 10.1145/3652037.3652073

Rahman, S. M. M. (2024). Dynamic affect-based motion planning of a humaoid robot for human-robot collaborative assembly in manufacturing. In *Electronics* (Vol. 13 (6), pp. 1–32). MDPI. doi: 10.3390/electronics13061044

Rajanen, D., Clemmensen, T., Iivari, N., Inal, Y., Rızvanoğlu, K., Sivaji, A., & Roche, A. (2017). Ux professionals' definitions of usability and ux - a comparison between turkey, finland, denmark, france and malaysia. In R. Bernhaupt, G. Dalvi, A. Joshi, D. K. Balkrishan, J. O'Neill, & M. Winckler (Eds.), *16th ifip tc 13 international conference on human-computer interaction, interact 2017* (Vol. 10516, pp. 218–239). Springer, Cham. doi: 10.1007/978-3-319-68059-0_14

Remy, C., Gegenbauer, S., & Huang, E. M. (2015). Bridging the theory-practice gap: Lessons and challenges of applying the attachment framework for sustainable hci design. In *Proceedings of the 33rd annual acm conference on human factors in computing systems* (pp. 1305–1314). New York, NY, USA: Association for Computing Machinery. Retrieved from https://doi.org/10.1145/2702123.2702567 doi: 10.1145/2702123.2702567

Rieg, S., Carter, E. J., Fong, T., Forlizzi, J., & Steinfeld, A. (2021). Flailing, hailing, prevailing: Perceptions of multi-robot failure. recovery strategies. In *Proceedings of the 2021 acm/ieee international conference on human-robot interaction* (pp. 158–167). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3434073.3444659

Ries, E. (2017). *The lean startup - how today's entrepreneurs use continuous innovation to create radically successful businesses* (First International Edition ed.). New York, NY, USA: Currency, Crown Publishing Group.

Ringberg, T., Reihlen, M., & Rydén, P. (2019). The technology-mindset interactions: Leading to incremental, radical or revolutionary innovations. In *Journal of industrial marketing management* (Vol. 79, pp. 102–113). Elsevier Inc. doi: 10.1016/j.indmarman.2018.06.009

Roedl, D. J., & Stolterman, E. (2013). Design research at chi and its applicability to design practice. In *Proceedings of the sigchi conference on human factors in computing systems* (pp. 1951–1954). New York, NY, USA: Association for Computing Machinery. Retrieved from https://doi.org/10.1145/2470654.2466257 doi: 10.1145/2470654.2466257

Rogers, A., Wendy, Kadylak, T., & Bayles, M. A. (2022). Maximizing the benefits of participatory design for human-robot interaction research with older adults. In *Human factors: The journal of the human factors and ergonomics society* (Vol. 64 (3), pp. 441–450). Sage. doi: 10.1177/00187208211037465

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction design - beyond human-computer interactoin* (3rd ed.). John Wiley & Sons Ltd, The Atrium, Southeren Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom: John Wiley & Sons Ltd.

Rohn, J. A. (2007). How to organizationally embed ux in your company. In *Interactions* (Vol. 14 (3), pp. 25–28). New York, NY, USA: Association for Computing Machinery. doi:

10.1145/1242421.1242440
Rosenberg, N. O. S., Chauvet, M.-C., & Kleinman, J. S. (2015). Leading for a corporate culture of design thinking. In S. Swan, M. G. Luchs, A. Griffin, M. I. Luchs, & S. Swan (Eds.), *Design thinking : New product development essentials from the pdma* (pp. 173–186). Hoboken, New Jersey: John Wiley & Sons, Incorporated.
Rossi, S., Rossi, A., & Dautenhahn, K. (2020). The secret life of robots: Perspectives and challenges for robot's behaviors during non-interactive tasks. In *International journal of social robotics* (Vol. 12, pp. 1265–1278). Springer. doi: https://doi.org/10.1007/s12369-020-00650-z
Rubinstein, D., & Meko, H. (2024, Feb). *Goodbye for now to the robot that (sort of) partrolled the nyc subway.* Retrieved from https://www.pressreader.com/usa/the-boston-globe/20240203/281715504509199
Rylander, A. (2012). Pragmatism and design research - an overview.. Retrieved from https://api.semanticscholar.org/CorpusID:41616934
Salah, D., Paige, R. F., & Cairns, P. (2014). A systematic literature review for agile development processes and user centred design integration. In *Proceedings of the 18th international conference on evaluation and assessment in software engineering* (pp. 1–10). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2601248.2601276
Salvini, P., Ciaravella, G., Yu, W., Ferri, G., Manzi, A., Mazzolai, B., … Dario, P. (2010). How safe are service robots in urban environments? bullying a robot. In *19th international symposium in robot and human interactive communication* (pp. 368–374). Viareggio, Italy: IEEE. doi: 10.1109/ROMAN.2010.5654677
Sandoval, E. B., Brown, S., & Velonaki, M. (2018). How the inclusion of design principles contribute to the development of social robots. In *Proceedings of the 30th australian conference on computer-human interaction* (pp. 535–538). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3292147.3292239
Satake, S., Kanda, T., Glas, D. F., Imai, M., Ishiguro, H., & Hagita, N. (2009). How to approach humans? - strategies for social robots to initiate interaction. In *2009 4th acm/ieee international conference on human-robot interaction (hri)* (pp. 109–116). California, USA: IEEE. doi: 10.1145/1514095.1514117
Seidelin, C., Sivertsen, S. M., & Dittrich, Y. (2020). Designing an organisation's design culture: How appropriation of service design tools and methods cultivates sustainable design capabilities in smes. In *Servdes.2020 tensions, paradoxes and plurality conference proceedings* (pp. 11–31). Melbourne, Australia. Retrieved from https://ep.liu.se/en/conference-article.aspx?series=ecp&issue=173&Article_No=1
Shah, S. K., & Corley, K. G. (2006). Building better theory by bridging the quantitative-qualitative divide. In *Journal of management studies* (Vol. 43 (8), pp. 1821–1835). Blackwell Publishing Ltd. doi: 10.1111/j.1467-6486.2006.00662.x
Sharp, H., Giuffrida, R., & Melnik, G. (2012). Information flow within a dispersed agile team:

A distributed cognition perspective. In C. Wohlin (Ed.), *Agile processes in software engineering and extreme programming lecture notes in business information processing* (Vol. 111, pp. 62–76). Berlin, Heidelberg: Springer. doi: 10.1007/978-3-642-30350-0_5

Sheppard, B., Kouyoumjian, G., Sarrazin, H., & Dore, F. (2018). *The business value of design* (McKinsey Quarterly Report). Retrieved from `https://www.mckinsey.com/capabilities/mckinsey-design/our-insights/the-business-value-of-design`

Shiomi, M., Sakamoto, D., Kanda, T., Ishi, C. T., Ishiguro, H., & Hagita, N. (2008). A semi-autonomous communication robot - a field trial at a train station. In *Hri '08: Proceedings of the 3rd acm/ieee international conference on human robot interaction* (pp. 303–310). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1349822.1349862

Simonÿ, C., Specht, K., Andersen, I. C., Johansen, K. K., Nielsen, C., & Agerskov, H. (2018). A ricoeur-inspired approach to interpret participant observations and interviews. In *Global qualitative nursing research* (Vol. 5, pp. 1–10). SAGE Publications. doi: 10.1177/233339361880739

Stark, J. L. (2014). The potential of deweyan-inspired action research. In *Journal of education and culture* (Vol. 30 (2), pp. 87–101). John Dewey Society. doi: 10.5703/educationculture.30.2.87

Stock-Homburg, R. (2022). Survey of emotions in human-robot interactions: Perspectives from robotic psychology on 20 years of research. In *International journal of social robotics* (Vol. 14, pp. 389–411). Springer. doi: 10.1007/s12369-021-00778-6

Svanæs, D., & Gulliksen, J. (2008). Understanding the context of design - towards tactical user centered design. In *Proceedings of the 5th nordic conference on human-computer interaction: Building bridges* (pp. 353–362). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/1463160.1463199

Sy, D. (2007). Adapting usability investigations for agile user-centered design. In *Journal of usability studies* (Vol. 2 (3), pp. 112–132). Bloomingdale, IL: Usability Professionals' Association. doi: 10.5555/2835547.2835549

Taylor, B., Henshall, C., Kenyon, S., Litchfield, I., & Greenfield, S. (2018). Can rapid approaches to qualitative analysis deliver timely, valid findings to clinical leaders? a mixed methods study comparing rapid and thematic analysis. In *Bmj open* (Vol. 8, pp. 1–13). BMJ. doi: 10.1136/bmjopen-2017-019993

Thrun, S. (2004). Toward a framework for human-robot interaction. In *Human-computer interaction* (Vol. 19, pp. 9–24). Lawrence Erlbaum Associates, Inc. doi: 10.1207/s15327051hci1901\%262_2

Thunberg, S., & Ziemke, T. (2020). Are people ready for social robots in public spaces. In *Proceedings of the 2020 acm/ieee international conference on human-robot interaction* (pp. 482–484). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3371382.3378294

Tonkin, M., Vitale, J., Herse, S., Williams, M.-A., Judge, W., & Wang, X. (2018). Design methodology for the ux of hri: A field study of a commercial social robot at an airport. In *Proceedings of the 2018 acm/ieee international conference on human-robot interaction* (pp. 407–415). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3171221.3171270

Tulli, S., Ambrossio, D. A., Najjar, A., & Lera, F. J. R. (2019). Great expectations & aborted business initiatives: The paradox of social robot between research and industry. In *Bnaic/benelearn 2019* (pp. 1–10).

Tushman, M., & Nadler, D. (1986). Organizing for innovation. In *California management review* (Vol. 28 (3), p. 74-92). doi: 10.2307/41165203

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. In *Nursing & health sciences* (Vol. 15, pp. 398–405). Wiley Publishing Asia Pty Ltd. doi: 10.1111/nhs.12048

Varsaluoma, J., & Sahar, F. (2014). Usefulness of long-term user experience evaluation to product development: Practitioners' views from three case studies. In *Proceedings of the 8th nordic conference on human-computer interaction: Fun, fast, foundational* (pp. 79–88). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/2639189.2641218

Venture, G., & Kulić, D. (2019). Robot expressive motions: A survey of generation and evaluation methods. In *Transactions on human-robot interaction* (Vol. 8 (4)). New York, NY, USA: Association for Computing Machinery. doi: https://doi.org/10.1145/3344286

von der Puetten, A. R., Sirkin, D., Abrams, A., & Platte, L. (2020). The forgotten in hri: Incidental encounters with robots in public spaces. In *Proceedings of the 2020 acm/ieee international conference on human-robot interaction* (pp. 656–657). New York, NY, USA: Association for Computing Machinery. doi: https://doi.org/10.1145/3371382.3374852

Šabanović, S. (2010). Robots in society, society in robots: Mutual shaping of society and technology as a framework for social robot design. In *International journal of social robotics* (Vol. 2, pp. 439–450). Springer. doi: 10.1007/s12369-010-0066-7

Šabanović, S., Meisner, E., Caporael, L. R., Isler, V., & Trinkle, J. (2009). 'outside-in' design for interdisciplinary hri research. In *Aaai spring symposium: Experimental design for real-world systems* (pp. 41–48). Stanford, California, USA: Association for the Advancement of Artificial Intelligence.

Šabanović, S., Michalowski, M. P., & Caporael, L. R. (2007). Making friends: Building social robots through interdisciplinary collaboration. In *Multidisciplinary collaboration for socially assistive robotics, papers from the 2007 aaai spring symposium* (pp. 71–77). Stanford, California, USA.

Šabanović, S., Reeder, S. M., & Kechavarzi, B. (2014). Designing robots in the wild: In situ prototype evaluation for a break management robot. In *Journal of human-robot interaction* (Vol. 3 (1), pp. 70–88). doi: 10.5898/JHRI.3.1.Sabanovic

Väänänen-Vainio-Mattila, K., Roto, V., & Hassenzahl, M. (2008). Towards practical user experience evaluation methods. In E.-C. Law (Ed.), *Proceedings of the international workshop on meaningful measures: Valid useful user experience measurement (vuum)* (pp. 19–22). Reykjavik, Iceland.

Wale-Kolade, A., Nielsen, P. A., & Päivärinta, T. (2013). Usability work in agile systems development practice: A systematic review. In H. Linger, J. Fisher, A. Barnden, C. Barry, M. Lang, & C. Schneider (Eds.), *Building sustainable information systems: Proceedings of the 2012 international conference on information systems development* (pp. 569–582). Springer, Boston, MA. doi: 10.1007/978-1-4614-7540-8_44

Wallström, J., & Lindblom, J. (2020). Design and development of the usus goals evaluation framework. In C. Jost et al. (Eds.), *Human-robot interaction* (Vol. 12, pp. 177–201). Springer Cham. doi: 10.1007/978-3-030-42307-0_7

Weiss, A., Bernhaupt, R., & Tscheligi, M. (2011). The usus evaluation framework for user-centered hri. In K. Dautenhahn & J. Saunders (Eds.), *New frontiers in human-robot interaction* (pp. 89–110). Amsterdam: John Benjamins Publishing Co. doi: 10.1075/ais.2.07wei

Weiss, A., & Spiel, K. (2022). Robots beyond science fiction: mutual learning in human-robot interaction on the way to participatory approaches. In *Ai & society* (Vol. 37 (2), pp. 501–515). Springer. doi: 10.1007/s00146-021-01209-w

Winkle, K., Senft, E., & Lemaignan, S. (2021). Leador: A method for end-to-end participatory design of autonomous social robots. In M. M. A. De Graaf (Ed.), *Frontiers in robotics and ai* (Vol. 8, pp. 1–18). doi: 10.3389/frobt.2021.704119

Yamada, S., Kanda, T., & Tomita, K. (2020). An escalating model of children's robot abuse. In *Proceedings of the 2020 acm/ieee international conference on human-robot interaction* (pp. 191–199). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3319502.3374833

Yigitbas, E., Jovanovikj, I., & Engels, G. (2021). Simplifying robot programming using augmented reality and end-user development. In C. Ardito & et al (Eds.), *Human-computer interaction – interact 2021* (Vol. 12932, pp. 631–651). Springer, Cham. doi: 10.1007/978-3-030-85623-6_36

Yin, R. K. (2016). *Qualitative research from start to finish* (Second ed.). 370 Seventh Avenue, Suite 1200, New York, NY 10001: The Guilford Press.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (Sixth ed.). Los Angeles, USA: SAGE Publications, Inc.

Young, J. E., Sung, J., Voida, A., Sharlin, E., Igarashi, T., Christensen, H. I., & Grinter, R. E. (2011). Evaluating human-robot interaction. In *International journal of social robotics* (Vol. 3, pp. 53–67). Springer. doi: 10.1007/s12369-010-0081-8

Zaina, L. A. M., Sharp, H., & Barroca, L. (2021). Ux information in the daily work of an agile team: A distributed cognition analysis. In D. P. Brumby (Ed.), *International journal of* *human-computer studies* (Vol. 147). Elsevier Ltd. doi: 10.1016/j.ijhcs.2020.102574

Zhong, V. J., & Schmiedel, T. (2021). A user-centered agile approach to the development of a real-world social robot application for reception areas. In *Companion of the 2021 acm/ieee international conference on human-robot interaction* (pp. 76–80). New York, NY, USA: Association for Computing Machinery. doi: 10.1145/3434074.3447132

Øvad, T., & Larsen, L. B. (2015). The prevalence of ux design in agile development processes in industry. In *Agile conference* (pp. 40–49). IEEE. doi: 10.1109/Agile.2015.13

Øvad, T., & Larsen, L. B. (2016). How to reduce the ux bottleneck - train your software developers. In *Behaviour & information technology* (Vol. 35:12, pp. 1080–1090). Taylor & Francis Group. doi: 10.1080/0144929X.2016.1225818

A UX MATURITY ASSESSMENT

The assessment is based on Jacob Nielsen's UX maturity model, which is thoroughly explained by Pernice et al. (2021) at the NNgroup's website, and which can be accessed through the link: The 6 Levels of UX Maturity.

STRATEGY Between Stage 1-2, closer to **1**

Vision (*Stage 2)*: End-users (i.e., operators and supervisors) are mentioned and sporadically considered, but they do not seem to be the main focus.

Planning & prioritization (*Stage 1-2, closer to* ***1****)*: No UX Designer was formally or officially assigned to the project but joined out of interest and availability. The project had no plan nor strategy for doing UX work or user research activities (main focus: UI). For a long time, UX has not been prioritized.

Budget (*Stage 1)*: Not aware of any budget exclusively for UX work. There is a budget for UI work and a contract with UI providers, but this does not include UX or user research activities, and it is up for re-negotiation (varying opinions and priorities).

PROCESS Stage 1, slowly progressing to Stage 2

Methods (*Stage 2)*: Some UX work (e.g., usability) had been done in the past (2018) by someone no longer in the company, but they may not have used the appropriate methods nor applied them correctly. Recent attempts also haven't proved successful in providing actionable insights resulting in a negative attitude "*I don't even bother*". This could be due to lack of UX skills.

Collaboration (*Stage 1-2)*: Product Managers have emphasized the need for user and UX considerations in the project and across the organization several times but are ignored or dismissed. UX has not been considered throughout the development.

Consistency (*Stage 1)*: Past UX and user research activities have been done one-off and non-reproducible (undocumented), and because those efforts provided poor and inaccurate results, it was decided not to pursue it further, thus no consistency.

CULTURE Stage 1

Awareness (*Stage 1-2)*: UX awareness is affected by a lack of understanding the *value* of UX *and* in some situations there is a problematic misunderstanding about what UX is. Some team members do consider users to some extent; through user stories or trying to predict possible (mis-)use of the robot, while others are solely focused on the tech. specs., and works out of memory rather than attending to user stories. There is a big risk that the team overlooks important user behavior and needs.

Appreciation & support (*Stage 1 with Stage 2 characteristics)*: Few people strongly advocate for UX and user considerations, while others are convinced that they know all that they need to know about their users because they have spent time with them in the past. While Product Managers are eager to include and consider UX and users, they are often misunderstood, interrupted, or shutdown by others in the team (often developers).

Competency (*Stage 1 with Stage 2 characteristics)*: Initially the project had no UX profile involved and UX activities were neither planned nor defined, the team lacks a UX mindset (occasionally mentioning that the user should be considered is not enough). Past UX work happened rarely, inefficiently, and without proper documentation or reproducibility, and user insights are often anecdotal rather than based on findings from user research.

Adaptability (*Stage 3)*: Few team members are motivated and interested in changing their practices and incorporating UX, but the rest of the team doesn't seem to be ready, which puts them in an awkward position of not being able to evolve or adjust because they depend on others.

OUTCOMES Stage 1

Measurement (*Stage 1)*: No UX metrics, KPIs, OKRs, or goals. Difficulties in articulating what they want to test and learn about users, and what is considered acceptable, e.g., in terms of completing a user story (based on whether it gets implemented). Rely on release road maps.

Impact of the design (*Stage 1)*: Design choices are driven by features rather than usability or user insights. Features are chosen, backlogged, and implemented without user studies or feedback from authentic users. This is partially based on internal feedback, developer's mindset, gut-feeling, or high-level (undocumented) conversations with, e.g., customers and sales representatives.

Figure A.1: UX Maturity Assessment of the Robotic Business Unit in the large, well-established company.

B PAPER CONTRIBUTIONS

The dissertation comprises of the four research papers listed below and included throughout the following pages.

1. **Nielsen, S.**, Ordoñez, R., Hansen, K.D., Skov, M.B., and Jochum, E.: RODECA: A Canvas for Designing Robots. 2021. In Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction. Association for Computing Machinery, Boulder, CO, USA, 266–270. https://doi.org/10.1145/3434074.3447173

2. **Nielsen, S.**, Skov, M.B., Hansen, K.D., and Kaszowska, A.: Using User-Generated YouTube Videos to Understand Unguided Interactions with Robots in Public Places. 2023. In ACM Transaction on Human-Robot Interaction. https://doi.org/10.1145/3550280

3. **Nielsen, S.**, Skov, M.B., and Bruun, A.: User Experience in Large-Scale Robot Development: A Case Study of Mechanical and Software Teams. 2023. In Human-Computer Interaction INTERACT'23. https://doi.org/10.1007/978-3-031-42283-6_3

4. **Nielsen, S.**, Ordoñez, R., Skov, M.B., and Jochum, E.: Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Large Organization Developing Robots. 2023. In Journal of Behaviour & Information Technology. Taylor & Francis Group. https://doi.org/10.1080/0144929X.2023.2227284

B.1 Paper 1

RODECA: A Canvas for Designing Robots

Abstract

Although there are existing frameworks for designing robots within the field of HRI, there is not yet a viable, all encompassing framework that bridges the gap between academic research, industry development and users in the design process. Through two online workshops and an individual company assignment, we identified industry needs, concerns and challenges relevant to the development of the Robot Design Canvas (RODECA). We present our preliminary work with seven industry partners and scientists from three research institutions. This research will inform the development of a versatile robot design framework that accounts for user experience early in the design process that can be validated through systematic investigation across research and industry applications. Such a tool would help bridge the gap between HRI research and commercial robot development.

Paper 1

Nielsen, S., Ordoñez, R., Hansen, K.D., Skov, M.B., and Jochum, E.: RODECA: A Canvas for Designing Robots. 2021. In Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction. Association for Computing Machinery, Boulder, CO, USA, 266–270. DOI: 10.1145/3434074.3447173

B.2 Paper 2

Using User-Generated YouTube Videos to Understand Unguided Interactions with Robots in Public Places

Abstract

Professional service robots are increasingly being deployed in public places, which thus increases user exposure. However, we lack an empirical understanding of complex encounters taking place in dynamic and often crowded environments as well as how people overcome breakdowns during unguided interaction with a robot in a real-world scenario. In this paper, we conducted a covert, digital ethnographic study analyzing 104 user-generated YouTube videos focusing on people's unguided interactions with robots in several public places. We identified several types of interaction breakdowns pertaining to someone (**person-initiated interaction breakdown, IB**) or something (**environmental disturbances, ED**) having a direct, negative effect on an ongoing unguided interaction. Our findings have implications for the design and development of service robots facing multi-user scenarios entertaining active (primary and secondary) users, inactive (commentators and observers) 'users', and **Incidentally Co-present Persons (InCoPs)**. Furthermore, we contribute to and built on the limited prior use of YouTube videos and digital ethnography in HRI research, thereby demonstrating its effectiveness in studying unguided interactions in public places, while supplementing and adding to the existing knowledge base of service robots in public places.

Paper 2

Nielsen, S., Skov, M.B., Hansen, K.D., and Kaszowska, A.: Using User-Generated YouTube Videos to Understand Unguided Interactions with Robots in Public Places. 2023. In ACM Transaction on Human-Robot Interaction. DOI: 10.1145/3550280

B.3 Paper 3

User Experience in Large-Scale Robot Development: A Case Study of Mechancial and Software Teams

Abstract

User experience integration within software companies has been studied extensively, but studies on organizations that develop robots are scant. The physical and socially situated presence of robots poses unique design and development challenges, which companies should be able to address. This case study examines how mechanical and software teams involved in a large-scale robot development project embed UX in robot design. The case offers new perspectives on HCI research, which traditionally explores UX integration in companies from the point of views of UX specialists and software developers, with little consideration of how mechanical and software design interact. During our 12+ months collaboration with the company, we conducted non-participant observations of 30 project SCRUM meetings. Based on this data, we identify four themes concerning the role of UX in robot development, workarounds in design evaluation, requirements handling, and coordination mechanisms.

Paper 3

Nielsen, S., Skov, M.B., and Bruun, A.: User Experience in Large-Scale Robot Development: A Case Study of Mechanical and Software Teams. 2023. In Human-Computer Interaction INTERACT'23. DOI: 10.1007/978-3-031-42283-6_3

B.4 Paper 4

UX Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Robotics Company

Abstract

Integrating UX into industry practices is a well-researched topic particularly for software companies. However, little is known about how UX integration and adoption 'works' within the robotics industry. This study identifies behaviours impeding UX adoption at the individual, team, and organisational level within a company developing robots. We carried out a one-year long Action Research study in a large, international company during design and development of a service robot. Based on a UX maturity assessment, we carried out six interventions, where the researcher and practitioners worked deliberately with UX competence-development and the company's UX culture. Together we identified six barriers: achieving appropriate confidence levels, trust in UX, commitment and support structures, trade-offs in UX, handover practices, and UX management. To address these barriers, we developed and tested 21 strategies to help foster good UX practices and promote a 'UX-friendly' culture that empowers non-UX professionals to drive user-involved initiatives themselves.

Paper 4

Nielsen, S., Ordoñez, R., Skov, M.B., and Jochum, E.: Strategies for Strengthening UX Competencies and Cultivating Corporate UX in a Large Organization Developing Robots. 2023. In Journal of Behaviour & Information Technology. Taylor & Francis Group. DOI: 10.1080/0144929X.2023.2227284