UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Socially responsible design for social robots in public spaces

by Meg Tonkin

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Doctor of Philosophy

under the supervision of Professor Mary-Anne Williams and Dr Benjamin Johnston

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Meg Tonkin* declare that this thesis, is submitted in fulfilment of the requirements for the award of *Doctor of Philosophy*, in the *School of Computer Science*, *Faculty of Engineering and Information Technology* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

Social robots are an innovative technology using artificial intelligence (AI), that can combine social, physical and digital interactions to create unique user experiences. Potential applications require a good user experience to encourage adoption by people. Social robots can also be considered surveillance devices, with sensors, image recording and AI that can identify faces and emotions. Therefore, organisations deploying social robot applications must meet privacy legislation requirements regarding the personal data used and collected in an interaction. Furthermore, to be socially responsible, organisations must behave in a manner that benefits society. Hence deploying a social robot in a public space must be carefully managed for the impact it might have on people within that environment. Design methods, that incorporate privacy considerations for public spaces and that enable a good user experience, are not yet available.

This dissertation contributes a design framework for organisations, that enables discovering potential applications, designing these applications with consideration for both privacy and user experience, and implementing these applications for use with humanoid social robots in public spaces.

This research used an Action Design Research (ADR) approach to develop methods that allow organisations to discover and implement socially responsible social robot applications, incorporating purposefully designed User Experience (UX) and privacy considerations, in public spaces. Embodying ADR principles of practice-inspired research and theory-ingrained artifact, two experiments were firstly undertaken.

The first experiment indicated that a social robot could function as a social agent, effectively undertaking a task requiring social engagement. However, greater value for organisations might be realised through applications utilising the full capabilities of a social robot across the social, physical and digital realms. The second experiment investigated privacy and UX, discovering that people may provide more personal information to a humanoid robot than to a kiosk when using transparency, which is a core component of Privacy-by-Design. Both experiments contributed to the development of a UX Human-Robot Interaction (HRI) design framework for social robot applications, that combines Lean UX (composed of Lean Startup, Design Thinking and Agile practices), privacy theory and HRI theory.

This UX-HRI framework was refined in iterative cycles of building, testing and evaluating social robot applications with design studies in three different environments, using the ADR principles of reciprocal shaping, mutually influential roles, and authentic and concurrent evaluation. Design principles were formulated through the generalisation of the context-specific findings. Guided by this UX-HRI design framework, socially responsible social robot applications can be created.

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Finally, I would like to pay respect to country, to the Elders—past, present and emerging—acknowledging them as the traditional custodians of knowledge on this land, on which this research has been undertaken.

List of Publications

Related to the Thesis :

1. Privacy by design in machine learning data collection: a user experience experimentation [397]
2. Would you like to sample? Robot engagement in a shopping centre [384]
3. Embodiment, privacy and social robots: May I remember you? [383]
4. Design methodology for the UX of HRI: A field study of a commercial social robot at an airport [382]
5. Be more transparent and users will like you: A robot privacy and user experience design experiment [396]
6. Privacy First: Designing Responsible and Inclusive Social Robot Applications for in the Wild Studies [381]

Others :

7. Bon appetit! robot persuasion for food recommendation [171]
8. Do you trust me, blindly? Factors influencing trust towards a robot recommender system [172]
9. UTS Unleashed! RoboCup@ Home SSPL Champions 2019 [300]

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Part I

Introduction

CHAPTER 1

INTRODUCTION

"The success or failure of robots will no longer depend on their technical capabilities alone, but also on the social construction of their use and fit with the environment" Selma Šabanović [329, p. 1]

At this moment in time we are at the dawn of social robots entering the everyday. We are witnessing a unique moment in history, as social robots pop up in public spaces such as shopping centres, art galleries, hospitals, museums and convention centres. Ordinary people are beginning to experience real life interactions with robots, which for the majority of the population were previously only experienced through films and TV. The changes to social order and the way it may change us are still to be discovered.

While industrial robots have been around for more than 30 years, kept inside safety cages in factories, social robots are more recent phenomena, built to be around people as colleagues, collaborators, and companions. They are designed to be capable of safely and autonomously moving around and communicating with humans, and to understand and follow human social behaviours in interactions by using the latest in artificial intelligence. Breazeal describes a social robot as *"...socially intelligent in a human-like way, and interacting with it is like interacting with another person."* [43, p. 1]

Commercially available, off-the-shelf robots, built with technology specifically for interacting with people are now readily available[1] and slowly being deployed in real life situations. However, so far, their adoption is limited and the challenges, as identified in Human-Robot Interaction (HRI) research [19, 42, 323, 331], in implementing this type of technology in the real world outside of laboratory studies, are numerous. Even with technical aspects successfully functioning, people can be scared away due to poor social interaction design, leading to rejection of the technology [109, 215]. While current social robotics research has been able to provide direction in some specific interactions, guidelines based on real world implementations are missing.

Moreover, clear value propositions are only slowly materialising for businesses [418], limiting the uptake of these social robots. Indeed very few studies exist describing how to design a social robot application that fits into the social and physical environment, works autonomously and meets an identified need or goal of people or organisations in that environment.

Additionally, concerns regarding the ethical use and societal impact of AI technologies have led to media articles forecasting doom [378], adding to people's fears of AI and of robots taking over [61, 262], stealing peoples' jobs [348] and even irretrievably changing society as we know it [126, 378, 395]. While concerns may be justifiable and must be addressed [274], this may add to a reluctance in social robot adoption, as organisations strive to avoid negative media and potential backlash from customers concerned with these issues.

Furthermore, human-robot interaction (HRI) research requires further transferability. HRI research has limited studies that have been performed in real world social settings, with social robots in public spaces meeting socially responsible, privacy respecting design, suitable for organisational practices. Moreover, it is only relatively recently that interest in ethical use and socially responsible robot applications, especially as regards to privacy, has begun to gain traction in HRI research. Ethical guidelines [112], design principles and checklists [117] have been put forward, however they don't provide mechanisms by which to instantiate the principles in a real world application, nor are they supported by examples of use in real world use cases. For example, Felzmann *et al.* [117] provide a checklist for transparency design for robots. However, it is still to be trialled on a concrete use case. Hence, there is limited direct transferability of HRI research for creating socially responsible applications for organisations and business purposes.

Taken together, these factors highlight the need for studies which involve real world,

[1] https://www.softbankrobotics.com/emea/en/pepper https://pal-robotics.com/robot/

socially responsible, social robot applications, which can provide both ecological validity for HRI research and future directions for businesses. However, as will be shown in Chapter 2 there is a gap in the robotics literature—processes or methods describing how to identify and create these social robot applications for organisations, that fit responsibly into everyday environments, is missing.

With this research, I aim to enable the uptake of socially responsible, privacy-respecting, social robot applications for use in public spaces, by organisations, business and government.

My primary objective for this dissertation is to provide a novel design framework for identifying, designing, developing and implementing social robot applications. The design framework is intended as an effective, efficient, ethical and feasible method that can be used for both research and business purposes. It is based on human-centred design practices and user experience design strategies, adapted and integrated with the latest HRI research findings.

Secondly, the design framework is intended to promote socially responsible design. We are yet to discover what the full societal impact of social robots will be. However, a clear area of concern is the ability of social robots to act as highly effective surveillance devices and intrude on people's right to privacy. Data collection and processing by the robot is virtually invisible to people. Social robots can record video and audio, send information to the cloud or third parties and act in real time on analysis of data, all of which raises significant privacy issues. Hence the framework includes privacy protections, ensuring a Privacy-by-Design approach is incorporated into the conceptualisation of an application at the very beginning and throughout the methodology, and instantiated within the actual design itself.

To address the objectives of this research, I intend to explore the following:

1. Determine if differences in the mechanisms of effect from other fields by comparing social robots to humans and other technology

2. Identify if different or additional privacy considerations are required for social robot technology

3. Assess how these differences and privacy considerations affect the user experience for HRI

4. Identify methodology for discovery and identification of social robot applications

5. Identify how the privacy considerations and user experience (UX) design can be incorporated into the application design

6. Identify design principles and guidelines for application design, with mechanism for implementation

Investigating social robots "in the wild" [179, 330] is a significant challenge. Interactions may be open-ended and unstructured, environmental variables may be uncontrolled [331], non-intrusive evaluation and ethics approvals may be more difficult [323], engineering navigation is complex, and unexpected phenomena may occur. However, it is vital as perceptions may be different in the wild, to those reported in the lab [158]. If social robotics research is to move forward, the necessity of in the wild, environmentally situated research conducted in specific contexts of use is required [330]. This research aims to make it easier to do by providing different strategies and considerations, required for identifying and designing socially responsible robot applications for actual deployment, that meet genuine needs of real people in specific complex environments, with cross-disciplinary teams.

1.1 Contribution

The dominant contribution of this dissertation is to introduce and validate a framework for identifying, designing, developing and implementing social robot applications fit for use in real world environments. Design methodologies have previously been put forward for designing robot morphology (the physical design of the appearance of a robot) via Participatory Design [229] and recently, Design Thinking [263]. Contrastingly, this framework uniquely distinguishes itself by focusing instead on real world social robot *applications* for commercially available, pre-built, humanoid robots for use in public spaces. The framework addresses a gap within the existing literature and contributes towards both academic research and commercial research. The framework promotes the creation of socially and commercially useful applications able to be implemented in the real world, while also assisting researchers in identifying areas relevant for academic research and in increasing their output of ecologically valid experiments. This is of genuine value as it allows a shift in focus towards real world applications that may be implemented in the short—to medium-term, rather than only proposed, theoretical applications that are yet to be feasibly realised or developed in the real world.

The crucial points of difference between my work and existing approaches in the field are the following:

Holistic approach My approach assumes it is necessary to first understand and situate the application design in the specific environment and intended domains of use, providing a fit within the situated, social and business context. For organisations this specifically includes identifying touchpoints within a customer journey, enabling alignment with their customer experience strategy. Furthermore, it avoids just analysing distinct elementary components of disconnected interactions, whose value may then be lost when placed within the ongoing flow of interactions in an organisations real world environment. By including this bigger picture view, it allows accounting for social factors which may impact on the human-robot interaction and on society at large.

Combining academic and commercial research goals While great strides have been made in academic HRI research, it is possible to further increase the output of ecologically valid experiments by partnering with business or government organisations. Implementing social robot applications with or in an organisation's environment cannot be undertaken lightly, as it may have unintended ramifications on the staff and customers, people within the direct and broader environment, and subsequently affect the organisation's reputation. In contrast to other approaches, this work explicitly uses aspects of partnerships, and development with an organisation, to meet the objectives of both academic and commercial interests.

Human-centred design practices and HRI research The first principles of human centred design are to support human rights and human dignity [52]. The importance of human centred design, both for commercial success and society's well being, is being realised across the field. Recent HRI studies have begun to include human-centred design practices. However, my framework extends these explorations by integrating Agile development practices and HRI research, that includes the unique contributions in an interaction particular to social robots, into the framework.

Socially responsible and privacy-respectful focus Technology impacts and shapes society, and as we move towards a future where social robots are part of the every day, it is vital to consider the impacts they may have on our well-being and ability to flourish. Implementing robots in public spaces goes beyond the straightforward

issues of safety and utility. Protecting people's right to freedom from surveillance or from fear of surveillance and the right to private space in which to conduct their personal affairs are paramount issues to consider in social robot implementation.

The empirical studies, design tools and artifacts presented in this dissertation are also of independent value. These tools and artifacts include the following:

1. A privacy-protecting identity management system for users of shared-use social robots.
2. Design principles for socially responsible social robot application design
3. An innovative wayfinding application for use in large institutions
4. A design space articulation for social robot application design
5. A categorisation of social robot information flows and processing

1.2 Significance

"Artificial intelligence, automation, and the gig economy can free us from drudgery, enrich our leisure, and build societies of shared prosperity. They have equal potential to create mass unemployment, hollow-out lives, and worsen inequality. Putting human rights at the core of this new wave of technology in global markets will help define which road we choose." Phil Bloomer, Executive Director, Business and Human Rights Resource Centre [53]

Social robots can transform how organisations provide services, and, in the process, changes the customers and employees experience. As organisations increase their use of new technology and AI, the potential impact of their use requires careful management to avoid the creation of negative experiences, non-use and avoidance.

By providing a framework accounting explicitly for the uniqueness of social robots and mindful of the societal impact around their use, organisations can effectively trial and implement social robot applications without fear of costly mistakes or brand backlash. The framework is critical to enabling the creation of socially responsible social robot applications.

The framework provides practical methods for both academics and business interests to use, that ensures the creation of social robot applications that meet users needs and are in a form appropriate to the situated context. This includes meeting industry

expectations that the experience with the application should match their customer experience strategy, for example creating positive, effortless interactions [103].

The stakeholders for this work are the manufacturers of social robots, the organisations that purchase the robots and implement the social robot applications, and the people experiencing interactions with the social robot. Wider society as a whole is a secondary beneficiary of this work, as inclusive and socially responsible design can support human rights and add to the overall well-being of society.

1.3 Theoretical Perspective and Motivation

It is not possible to provide a methodology for organisations to implement social robots without an understanding of situational sociological processes. Humans mostly determine their actions based on the social order or social norms, in society [32]. However, with the increasingly rapid uptake of new technology, there is constant social change, and social norms can be observed to be changing. Social robots are *not yet* an integral component of most societies and interactive experience with social robots is still a novelty to the majority of people [362]. In human-robot interaction with social robots, new ontological categories may be emerging [201] that challenge the foundational, animate and inanimate, ontological categories.

Hence this investigation is constructed on an iterative basis of observation and abduction, grounded with HRI literature, tested by hypothesis and concrete evidence where possible, and presented with limitations outlined. Similarities are shared with value-sensitive design, yet this investigation provides values from the start: socially responsible design, with a focus on the right to privacy, and people's experiences around the technology.

The theoretical basis for this dissertation is one of acknowledging an approach of ontological realism (a real world exists independently of our perceptions, constructions and theories), and phenomenological and epistemological constructivism (understanding of this real world is a construction from our own perspectives, experiences and viewpoints) which allows broader investigation beyond the confines of a solely classical empirical experiment viewpoint. This juxtapositional approach parallels previous works within HRI literature, for example the works by Kahn *et. al* [200–202].

The goal is to provide a framework that includes the known considerations when attempting to implement a social robot in a public space. A methodology that explains what it is essential to know at our present time, regarding people and their actions, to

enable successful implementation and benefit to society. Motivating this research is the lessons learned from similar society-changing technologies such as the mobile phone and other devices, where privacy considerations were, and still sometimes are, only added after their adoption.

This research calls on several theories across disciplines HRI, HCI, UX, Interaction Design, Privacy Research, Public Spaces and Health, as foundations from which to structure this investigation.

The values I have chosen as the basis to guide this investigation and the reasons are outlined in the following:

- **Inclusive Design**
  Loebach *et al.* define inclusive design in public spaces as that which *"seeks to provide usability for as many people as reasonably possible. Users should feel that they have equitable access and are able to use spaces and interact with others with a sense of belonging"* [246, p. xxvii]. Inclusion in public spaces may be considered important to people's sense of well-being [60]. All possible people who may be in a public space deserve to be able to access and use the application. For example, children, the elderly, minority groups and people who may have difficulties hearing, seeing or cognitive impairments, must have access. This is especially important for government organisations, where a social robot may provide a service or offering that is intended for public use. Additionally, by being inclusive of all people and supporting the full range of human diversity, the application maximises potential uptake and use.

- **Social Responsibility**
  Social Responsibility is defined by the International Standards Organization (ISO), in ISO 2600 as the:
  "responsibility of an organisation for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour that
  - contributes to sustainable development, including health and the welfare of society;
  - takes into account the expectations of stakeholders;
  - is in compliance with applicable law and consistent with international norms of behaviour; and
  - is integrated throughout the organisation and practised in its relationships" [186].

  Therefore, any social robot application is designed and implemented so that the welfare of society, not just the benefit to the organisation, is considered.

A core principle of social responsibility is support and respect for human rights [186, 390]. This investigation is especially focused on privacy, as the right to privacy is in the universal declaration of human rights. Creating robotics applications that respect peoples right to privacy is paramount for organisations professing social responsibility. Robots are essentially data collection and surveillance machines. Therefore, the expectation is that the robotic application (and organisation responsible for it) maintains social norms regarding expectations of privacy and acts with integrity regarding information flow, transmission and sharing, data collection, use and transactions. It includes acting with integrity and transparency in communication, behaviours and actions. This extends further than the meeting of current legal requirement obligations around information collection and use.

1.4 Scope and Limitations

The conceptual framework proposed in this work is intended to be used by organisations, government institutions and academia, for identifying, designing, developing and implementing potential applications of social robots in public spaces, which respect privacy and are socially responsible.

The framework is evaluated for the ability to successfully identify potential applications for use in the wild (outside the laboratory or as close to that as possible) that will be used in the intended environment.

The following limitations exist for this work:

1. Commercially available, humanoid social robots, such as the Pepper robot, are the only robots investigated. Hence further research would be required to apply findings to robots of different morphology.

2. Experiments are conducted “in the wild”, and this brings a certain amount of unpredictable variability to findings, as environmental factors may be unstructured and cannot be predicted nor controlled.

3. This is a “snapshot” in time. Findings may be current for only this period in history and given the rate of technological change may be superseded within a short timeframe. Furthermore, the studies undertaken are limited in duration, hence differences may be observed in lengthier, longitudinal studies.

4. The problem of identifying, designing and implementing social robot applications is complex and emerging. Hence the framework will not cover every possibility, nor is it entirely prescriptive. A single doctoral student can contribute only so much to applied design research during a time-limited PhD project.

5. Inclusive design is a stated value of this research. However, it should be noted that while inclusive design assists in making a service more accessible, it doesn't mean that it will meet accessibility standards.

6. This research supports social responsibility, however, this is limited to a focus on the human right of privacy. The exploration of privacy may primarily be considered a 'western' approach, due to the wide availability of privacy research from this area. Future research with experimentation in different cultures will allow this to be expanded.

1.5 Dissertation Structure

This dissertation has the following structure:

- In the next chapter, I outline the reasons for this research, reviewing available literature and highlighting the gap in this area for social robot application design guidelines.

- The mixed methods research approach and initial research questions are described in Chapter 3.

- In Chapters 4 and 5, are described two studies identifying differences between robots, humans and other technology. The challenges of studying social robots in public spaces and the importance of privacy and how this inter-plays with the user experience is explored.

- In Chapter 6, a conceptual design framework is presented and detailed.

- Studies implementing the evolving design framework are presented in Chapters 7, 8 and 9, and across three different and complex environments.

- The dissertation concludes with the framework for social robot implementation, limitations and areas for further investigation.

CHAPTER 2

LITERATURE REVIEW

"HRI problems are not restricted to a single human and a single robot, though this is certainly one important type of interaction." Michael Goodrich and Alan Schultz [150, p. 22].

This literature review chapter seeks to explore in greater depth the broad areas outlined as significant in the previous chapter. Identified is the gap in the human-robot interaction (HRI) literature regarding methodology for discovering and designing socially responsible social robot applications for use in public spaces that purposefully design the UX and respect privacy. The following four items are identified as areas to be addressed:

1. HRI design methods for discovering and creating viable, socially responsible use cases (applications) for public spaces
2. HRI design methods that include a full, iterative, UX process of analysis, design, implementation, and evaluation for public spaces
3. HRI design methods that include privacy considerations for public spaces
4. HRI design guidelines or principles that specifically address both UX and privacy for public spaces

This review firstly defines each area of interest to the research, its importance, the current studies in the field, and then identifies the methodology gap, as per the following sections:

- Section 2.1 defines the technology of interest—humanoid social robots and presents the specific robots of interest for this research.
- Section 2.2 describes public spaces and the implications for socially responsible applications and human-robot interaction. I examine the value of public spaces to society, and to the individual, reporting on its role in their wellbeing.
- Section 2.3 reviews the literature for studies of humanoid social robots in public spaces, investigating popular places: shopping malls, airports, museums, hotels and hospitals. These are assessed for relevant findings and methodologies used (or lack thereof) for discovering and implementing real world applications of social robots in public spaces.
- Section 2.4 defines user experience (UX) and the role of UX in HRI.
- Section 2.5 reviews studies in HRI investigating UX and highlights the gap in methodologies for designing the UX for social robots in HRI.
- Section 2.6 then turns to privacy, its value and importance. This is followed by the implications for HRI and privacy sensitive robotics, and the lack of design methods in HRI for privacy. I discuss the urgent need to incorporate privacy considerations into the design of social robot applications to ensure social responsibility.

Finally, the survey concludes by identifying the need for further literature regarding methodology for HRI. While broad design principles and ethical guidelines exist [112, 315], the mechanism through which the principles may be instantiated is still required. There is a lack of studies specifically for socially responsible, social robot application design and real world implementations that incorporate both privacy considerations and the user experience.

2.1 Social Robots

Social robots are those *"designed to interact with people in a natural, interpersonal manner"* [42, p. 1935]. Social robots can use both verbal and non-verbal signals to

communicate in a human-like, socially natural fashion. A social robot does not need to have a human-like shape for it to be considered a social robot. However, it must be able to display and respond to natural human social behaviour [125]. As such, even an autonomous vehicle may be considered to be a type of social robot [370].

Robotics labs perform the majority of reported social robot studies and may create their own social robot prototypes. Accordingly, a variety of prototypes are commonly seen in research papers. Thus, social robots can be a broad range of shapes and sizes, and it is difficult to review the literature with just one morphology in mind for study.

It should be noted that different descriptors of social robots exist, hence listed are descriptors used in the studies reviewed. Three main classifications are given by Yanco and Drury [426] for robot morphology:

1. Anthropomorphic
    a) Android—the most human-looking robot style, a robot that attempts to copy a humans' appearance exactly—skin, hair, eyes, size
    b) Humanoid—has human-like features, for example, a face, head, body or shape of a human, can be various sizes and colours, also may be on wheels instead of legs (for example C3-PO from the movie Star Wars is a humanoid)
2. Functional —also referred to as Industrial/non-biomimetic— a robot which may be built for a specific purpose hence determining the shape. A robot which does not take its shape based on natural forms (for example R2-D2 from Star Wars)
3. Zoomorphic —also referred to as Biomimetic—a robot that may be shaped as an animal such as a dog or a seal

For this dissertation, however, the social robot style of appearance that will be referred to and considered, unless otherwise specified, is that of a social robot with a humanoid appearance, having a torso, arms, head and representation of a face.

Two specific, commercially available, humanoid social robots are utilised in the studies described throughout this dissertation, and their images are displayed for reference here in Figure 2.1.

2.2 Public Spaces

The definition of public spaces broadly considered for this dissertation is in line with that of the United Nations Educational, Scientific and Cultural Organization. A *"public*

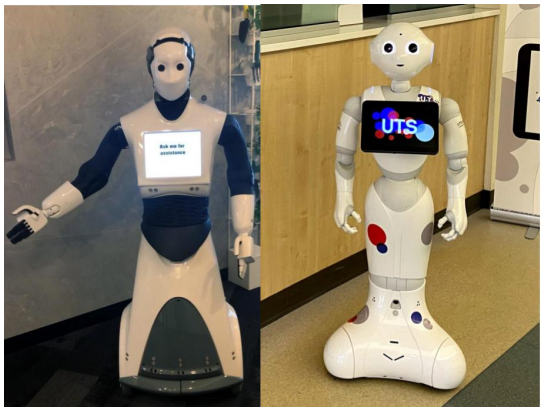


Figure 2.1: PAL REEM Robot and Softbank Pepper Robot

space refers to an area or place that is open and accessible to all peoples, regardless of gender, race, ethnicity, age or socio-economic level" [389]. Public spaces may be publicly owned and managed, or privately owned and accessible to the public within certain hours, places such as that of a shopping mall, airport or museum. "Public" in this context relating to the concept of use, not ownership [9].

Society regulates public spaces to serve political and social purposes, and additionally, people find meaning in public spaces. Technology must be introduced to public spaces with consideration of its impact upon society and people. Our social norms are closely tied to public space: *"The public space is also strongly regulated by laws, norms and institutionalised values, by daily routines and rituals, by cultural, social and political content and meanings."* [128, p. 3]. Consequently, there is also political significance to public space, as it may be considered the domain of citizenship, shaping people's understandings of identity and belonging [100]. Therefore, any new technology that is going to create change in the norms of a public space must be carefully considered for its impact on people and their sense of citizenship.

Introducing a social robot to a public space must be managed in a socially responsible manner to ensure the well-being of people. Public spaces may be considered an arena for social life where socio-cultural expectations meld with the physical setting, with positions in social structure setting expectations about appropriate behaviour and activities [78]. A public space allows people the opportunity to interact and socialise with each other and may be used for group or individual activities [58]. Inclusion in public spaces may be considered important to people's relations and sense of well-being [60, 246]. To ensure social responsibility and support for health and welfare of society, organisations must take seriously the impact on inclusiveness a robot may bring to a public space.

There is a psychological dimension to consider regarding public places. It should be noted that "space" and "place" are related terms. Spaces may be considered abstract environments that then turn into places when people assign value and meaning to the specific setting [9]. *"The term 'place', as opposed to space, implies a strong emotional tie, temporary or more long-lasting, between a person and a particular physical location."* [356, p. 50]. Rubinstein and Parmelee [325] put forward that it is the combined factor of personal experience and social interaction that can contribute to an individual attaching meaning to a place. This has been studied in areas such as recreation, tourism and retail [196, 221]. Meaning is attributed to places around three themes: self, others and environment, and the relationships between the three. The *self* involves self-identity, activities, experiences and memories. *Others* are the inhabitants in the place and their perceived characteristics, traits and behaviours. *Environment* is the physical setting e.g. physical features, symbolic and historical [156].

2.3 Social Robots in Public Spaces

Taking the psychological dimension of place into account, Fortunati *et al.* [128] discusses the possible transformation of public space by a social robot. He asserts that the presence of the social robot may affect people's psychological connection with places along with self-other or self-environment themes, and work in this area is explored. Fortunati *et al.* [129] conducted a study into perceptions of public spaces using the DORO robot in Pisa Square and a University auditorium in Udine, Italy. The study explored three different communicative uses of robots in public contexts. Fortunati *et al.*'s study is the first such study of social robots in a public space to delve into this concept of the social robot as being a complex, mobile communication hub and this idea is expanded upon further in later chapters of this dissertation. In Fortunati *et al.*'s study, it is argued that social robots should be seen according to Höflich's [178] triadic model that combines human, robot and environment. When social robots enter the public arena they *"have to deal with the complex, communicative, and relational* dispositif *of public space."* [129, p. 3].

A confirmation of this 'transformation of public space' by a social robot has also possibly occurred in real-life. Recent deployments of grocery store robots across Connecticut, USA have been described by customers as anxiety-inducing, suggesting the use of robots in the stores may well affect the psychological wellbeing of the store customers [139].

However, methodology for implementing social robots accounting for psychological factors of public spaces appears to be missing from the literature. Numerous studies

exist on specific scenarios and select factors to consider for interaction, such as proximity, gaze, conversational dialogue, and technical factors such as navigation, motion planning and social signal processing. Yet, there is a lack in how to bring all these together, to create and deploy the best experience, that avoids detrimental feelings, in the public space environment being considered.

Furthermore, a secondary issue exists for social robots in public spaces. In the Connecticut deployment, the value of the store robot in the space is questionable. While the store robot can navigate the aisles, it is reported that one of its tasks is to bring attention to hazards on the floor that might get in the way of people, such as spills or fallen items. Customers were amused that the robot is unable to clean up the spills, suggesting the value and purpose of the robot can be questioned.

These two issues, of both detrimental feelings experienced by customers and an unsuitable task chosen for the robot, suggest greater care must be taken before the deployment of robots in public spaces in real-life. Issues such as these may have an impact on customer loyalty and hence future profitability of the store. However, HRI research on how to avoid poor experiences and also provide a valuable task for the robot is limited.

Outlined in the following subsections are a small number of recent studies that explore creating viable applications for social robots in privately owned, yet publicly accessible spaces.

2.3.1 Social Robots in Shopping Malls and Airports

The MuMMER project (MultiModal Mall Entertainment Robot) [131] is the most recent, large scale undertaking of deploying a social robot in a shopping centre where marketing activities, help and guidance, and entertainment are the expected tasks.

Multiple papers have been published regarding this single 4-year project. Investigation of the role a Pepper robot could play in the shopping mall environment according to the expectations of management, retailers and customers found Pepper could positively add to the atmosphere of the shopping centre with entertainment and guidance [284]. The constraints perceived by retailers and management are provided in further detail by Niemelä *et al.* [285], and finding a balance between entertainment and utility is reported as vital. Positive, initial acceptance by customers of the Pepper robot in the mall was discovered, yet also expected [283]. The technical system and components used are comprehensively described in a paper by Foster *et al.* [132], with functions listed as

available for the robot *Chat*, *Quiz* (robot asks the questions, human replies) and *direction giving*, in the form of verbal instructions with pointing.

This ongoing MuMMER study is of interest to this project in two ways:

1. The development of the use case
2. The interaction behaviour provided

The development of the use case: The method to discover possible uses of the robot in the shopping mall is presented as Co-Design, with co-creation activities enabling stakeholder-generated ideas. While this admirably includes the end-user in the design process, no mention of meeting peoples' pain points or needs in the shopping mall environment occurs. The co-design methods described did not involve identifying pain points, or uncovering unmet needs, from which to use as a basis for ideation. Instead, people were quizzed as to how they might imagine a social robot might possibly be used in the location, without thinking about what problem the robot would be solving for them. In line with thinking by Brooks [46] and the '*Jobs to be Done*' framework by Christensen *et al.*[69] — what job is it that people have in this environment that it is important to them to get done? This is not apparent in the listed studies [284, 285]. In my view, without this knowledge, this may limit the value of the generated ideas and use cases put forward, as while they might appear as good ideas to try, it has been demonstrated that without an actual value provided by the robot (the fulfilling of a genuine need), people's use of the robot wains [92]. This is of specific interest, as discovering viable use cases is one of the stated goals of this research.

The interaction behaviour provided: Secondly, the interaction behaviour described for the task of providing directions is in a verbal manner with pointing. While this is perfectly reasonable and mimics a human, I suggest that it does not utilise the full multi-modal abilities of the robot. No added value can be ascertained as being provided by the robot for this task.

The MuMMER project is one of the most significant studies in shopping malls in recent years. Previous to the MuMMER project, studies of robots in shopping malls have also been conducted in regards to: assisting with conversations with elderly shoppers [190]; modelling of children's abuse of social robots to enable the robot to escape [50]; and shopping guide robots [204, 428], providing assistance to locate products [105, 155].

Also of interest to this research is the design method used in the study by Doering *et al.* User-centred design and evaluation were used for a shopping assistant robot, TOOMAS [105], which found shopping with the robot's assistance was as effective and

satisfactory as conventional shopping. The study undertook multiple empirical field studies, investigating the usability and acceptability of the robot and adjusting the design accordingly. This style of iterative design is of interest to this research and may be of value in social robot application design.

Providing guidance to people is a common theme in use cases for social robots, and this has also been explored in airports. The SPENCER project details the use of a socially aware mobile robotic platform to guide users in connecting flights [197, 385]. The SPENCER robot is able to scan people's boarding pass and then lead them to their destination gate. A Pepper robot providing a quiz in an airport environment made a better impression with shoppers than was achieved with the use of a kiosk [91].

2.3.2 Social Robots in Hotels and Museums

The collecting of customer feedback is a standard task that hotels perform currently [405], that is suggested could be facilitated by the use of robots. Chung and Cakmak [70] investigated this use case in five hotels and, based on their findings, believe robot-based feedback is a viable commercial application. The robot used was a Savioke relay robot, and the design approach employed multiple phases of prototyping with potential users in the hotel environment, to quickly learn critical design and implementation lessons [70]. Importantly, this is the only field study that has specifically called out privacy considerations in their design implications. The authors had stated that their guidelines were to *"respect customer privacy"* however they discovered that they had accidentally designed the behaviour of the robot interaction to breach this. The robot responded with bells and whistles when the hotel received five stars in feedback, alerting those surrounding the user (and vitally, the staff) as to what the *"anonymous"* feedback provided was. This suggests that an analysis of privacy impacts was not conducted on the application during development.

A similar, iterative design approach was employed for Sacarino, a bell-boy robot that provided hotel-related services such as calling taxis, bringing snacks and information guidance about the city [318]. Three factors were investigated: embodiment, robot awake/asleep and greeting model. It was discovered that interactions were longer when the robot was embodied, active and greeting customers.

Real world deployments of robots in hotels are also increasing in occurrence, and it is critical to understand the customer's experience in these situations to understand the improvements required to enhance future customer experiences [387]. Hospitality and tourism are primarily concerned with the experiences of visitors and the management

of experiences [44]. Tung and Au [387] analysed customer reviews left on internet sites TripAdvisor, Agoda, Yelp and Booking.com for four hotels with robotics applications, assessing the reported user experiences with the robots according to five dimensions evaluating user experiences in HRI (embodiment, emotion, human-oriented perception, feeling of security and co-experience). The study highlighted the influence of the robotic embodiment and the importance of human-orientated perception. Specifically of import was the ability of the robot to respond to events and commands. What this study suggests is that good customer experience with robots in hotels is still to be established. Furthermore, while Tung and Au explored enhancements for *improving* the current experiences, they did not propose ways to *design* a good customer experience for deploying robots.

Additionally, the use of robots in museums is considered a significant area of potential. Museums have explored trialling the use of social robots, with robots providing information guidance and explanation of exhibits [205, 351, 354, 379]. Long term implementations in museums have also been trialled and completed [290] and new trials have begun [146]. What is highlighted in all these studies is that, while a robot seems the ideal medium for providing that mix of interactivity, guidance and education required for museums, real world deployments are full of challenges.

2.3.3 Methodology for implementing Social Robots in Public Spaces

It is clear from all the presented examples of section 2.3 that there are few and incomplete methodologies for reliably discovering, designing or implementing social robot applications in these public space locations. The need for methodologies specifically for human-robot interaction has been ongoing for more than a decade, with Dautenhahn highlighting in 2007 the difficulty, and growing awareness of, the need for methods, methodologies and a conceptual basis for the HRI research field [89].

Dautenhahn put forward that as the field of HRI covers engineering, robotics, computer science, artificial intelligence (AI), human-computer interaction (HCI), psychology, cognitive science and the social sciences, it is not possible to simply transfer learnings and methodology from other fields across to HRI. Namely, HRI is not just an extension of previous efforts and work in other fields. There are distinct differences found in HRI from human-human interaction and human-computer interaction, and this must be considered.

There are also calls for efforts to bring consistency, rigour and scientific robustness

to the HRI field with, for example, the standardising of measures for experiments (Godspeed, RoSAS) [24, 57]. However, with the broad scope of disciplines and researchers brought together for HRI, consistency across research studies is still difficult. Baxter *et al.* brought this to the attention of the HRI community in 2016, by analysing publications from the previous three years [25]. They revealed that each disciplinary field brings its own assumptions and techniques with resulting differences in methods, difficulty in reproducing results and low use of comparable measures among researchers.

However, the challenge for consistency is not one of just picking one particular disciplines' research fields methods of research and following it, as stressed by both Dautenhahn [89] and Baxter *et al.* [25]. Both have maintained it is vital for the HRI research field to remain innovative and not restricted to any particular disciplinary perspective. Dautenhahn states "*there is no 'once-and-for-all' solution applicable across HRI*" [89, p. 103]. Consequently, it should be understood that any methodology put forward should be with the mindset that it will be only one of many approaches possible.

The limitation in methodology is across all areas of HRI, and not just for the stated focus area of applications for social robots in public spaces. In fact, any study conducted outside laboratories, 'in the wild' [20, 330], additionally suffer from this deficit, yet especially in HRI methodology. However, the open nature of participant's involvement in studies conducted in real world, public space environments brings additional real world challenges. For example, interactions are dynamic and may be unstructured; people may want to interact with the robot but not be a participant in a research study.

Accordingly, ethics approvals are a significant challenge for research studies in open environments. Signing of a participant informed consent form can change the feel from a real world setting and hence the natural interaction and therefore, research validity may be impacted. Attempting to address this issue, Sanoubari and Young [337] describe their design template for ethics approvals in real world settings. They poster the study area where the research trial is taking place and suggest the use of post-test debriefing. This was especially important in their study as they were using Wizard-of-Oz (WoZ) techniques, deceiving participants into thinking the robot was autonomous when in fact an operator was managing the robot and interaction, out of sight of the participant. On the whole, literature dealing with "how to's" for real world studies is very limited, in contrast to studies conducted in controlled or laboratory conditions, for which there is substantial literature to be found [23, 30, 198].

As such, it can be seen that literature outlining how to design for real world, public space studies, is limited. Design methods for discovering and creating viable, socially

responsible use cases (applications) for public spaces are required. Furthermore, as highlighted from the examples in section 2.3, literature outlining how to avoid detrimental feelings in social robot deployments for real world studies is similarly limited. Understanding of how to create a positive feeling around the placing of the robot in the public space is crucial. Designing positive user experiences is vital to people's acceptance of social robots [94] and user experience is now explored in the following section.

2.4 User Experience

This section examines User Experience (UX). The International Standards Organization (ISO), in ISO 9421, defines user experience as a "*person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service*". Included in the standard are two additional notes:

1. "*User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use.*"

2. "*User experience is a consequence of brand image, presentation, functionality, system performance, interactive behaviour and assistive capabilities of the interactive system, the user's internal and physical state resulting from prior experiences, attitudes, skills and personality, and the context of use.* "

From the above UX definition it is the second note that provides the item of most relevance for this research into social robotics in public spaces: *the context of use*. Up until comparatively recently, the majority of experiments regarding social robots have been undertaken inside laboratories [25], with the context of use being situated in the lab environment. The artificial environment inside a lab is excellent for controlling variables and isolating specific factors in an interaction, however the translation of the application of study to outside the lab is generally found to be limited in success [331], as factors related to the situational context affect the interaction. Hence increased studies "in the wild" to account for situational factors are recognised as vital to progressing HRI research while also allowing for unexpected social phenomena to occur [330].

Recognising the specific situation as a factor in user experience is vital when a social robot is placed in a public space. There may be social norms or social influence at play that will subsequently affect the user experience and change how users will interact with a robot.

UX involves both the pragmatic and the hedonic quality of the interaction [162]. The concept involves not just the ability of the user to achieve their intended goal easily, but the way the user felt while doing so, and the emotional impact of the interaction. Hassenzahl describes UX as the result of the interaction of the specific situation, a user's internal state and the attributes of the item of interest [163].

Hassenzahl's *perspective* on experience may also be the most appropriate for this research regarding social robots in public spaces: *"An experience is subjective, holistic, situated, dynamic, and worthwhile."* [163, p. 3]

2.4.0.1 Customer Experience

Before moving on to explore UX in HRI, a mention must be made of the difference between User Experience and Customer Experience (CX). It is generally considered in the industry that UX relates to specific product experiences, whereas CX instead focuses on the entire experience with the company's products, services, and interactions [15, 36, 183].

What is vital to understand is that the HRI user experience impacts the customer experience in a consumer situation [276]. This is recognised in the service and hospitality fields [37, 387]. However, the HRI literature on designing the customer experience and HRI with social robots in the real world is, to the best of my knowledge, minimal at best. Hence for this literature review, I focus on UX studies, with the knowledge of its importance in CX, and look to conduct future studies to address this gap concerning CX in research.

2.5 Social Robots and User Experience

2.5.1 User Experience in Social HRI

The realisation that positive user experience is vital for the acceptance and proliferation of robots in society is progressively being understood by the HRI community [7, 407]. Subsequently, user experience research has become of increasing importance in HRI research. The user experience is now considered by some as an additional factor to be designed and measured, beyond that of usability and acceptance of the robot [94]. The role and relevance of UX and UX design are of vital significance in social robotics [7] and prevalence of UX in HRI is limited but growing.

A comprehensive and recent review of UX in HRI is provided by Alenljung *et al.* [8] and an outline of the most salient points of the review are provided here. Four trends in UX HRI research studies were identified by Alenljung *et al.* [8] as an issue:

1. Positive UX is given as the reason to investigate a certain aspect, to include or omit a feature or attribute. Example: Matsumoto *et al.* discovered inappropriate and inconsistent expressions of emotion by a robot could alter the user experience for users viewing a movie and hence highlighted some design issues in this regard for enhancing positive UX [257]. There are situations however, where this behaviour could be beneficial, for example, the robot acting in a surprising way to elicit interest from the user [256].

2. The complexity of UX and all its complex facets are not considered. For example, one dimension of UX could positively enhance experience while another dimension could detract from it, and this is not considered in the studies.

3. The user is studied instead of the interaction between the user and the robot.

4. UX evaluation is conducted after the interaction, with potential biasing of results.

What is also clearly highlighted in Alenljung *et al.*'s review is that the major body of work of UX in HRI has been on *evaluation* of UX, not on the processes involved in designing a comprehensive UX, and even the literature on evaluation of UX in HRI is limited. The main literature on UX evaluation has been put forward by Weiss *et al.* [407] with the USUS framework. Alenljung *et al.* highlights that while this framework provides a comprehensive outline of the methods and techniques for assessing individual aspects of UX, it suggests this would be time-consuming if all UX factors were to be measured. It does not exactly address how to manage the measures concerning specified UX goals.

Alenljung *et al.* state that there is much-needed research guidance required on how to properly carry out user experience design activities that are specifically for social/socially interactive robots with specified UX goals. Roboticists need to understand the many interdependent factors of UX and the practical application of the appropriate evaluation method. They argue for adopting techniques from the UX and Human-Computer Interaction (HCI) fields and adapting these appropriately to HRI. This is in line with that proposed by Dautenhahn, that HCI and UX methodology could be useful for bringing to the HRI field [89].

In summary, Alenljung *et al.* put forward the areas to be addressed in HRI research with UX as the following:

1. Including, not just UX evaluation but the full UX design process, in HRI research, i.e. analysis, design, implementation and evaluation (as according to Hartson and Pyla [162])

2. Guidance on how to establish and prioritise UX requirements and goals

3. The lack of business perspective in UX design of socially interactive robotic products

It is clearly apparent that HRI design methods, that include a full, iterative, UX process of analysis, design, implementation and evaluation for public spaces, are still required for HRI research. However, UX is not the only area of interest for this dissertation. To be socially responsible requires respecting people's privacy. Hence, applications that are mindful of privacy and still provide the possibilities for meaningful experiences are required. Privacy, and how to design for privacy, are explored in the following sections.

2.6 Privacy

Privacy is elusive to define as it is a multi-faceted concept and means different things and has different values to different people [102, 120, 122, 252, 271, 364]. There appears to be no universally accepted definition, yet a general acceptance that it is a meaningful and valuable concept. The exploration of the whole idea of privacy is outside the scope of this dissertation. However, it is not possible to talk about privacy or privacy considerations without having some understanding of privacy. Therefore I outline some main theories, taxonomies and understandings of privacy, iterate the importance of privacy and, as I am specifically dealing with the UX of people interacting with social robots in public spaces in this research, I focus on consumer privacy. This is followed by a short review of HRI research concerning social robots and privacy and the new field of privacy sensitive robotics.

2.6.1 Privacy theories and concepts

A frequently cited concept of privacy is that of Warren and Brandeis, privacy is "*the right to be let alone*" [404, p. 193]. This implies that not being "let alone" would be detrimental in some way. A further idea of privacy is one of information transferal, as put forward by

Alan Westin *"Privacy is the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others"* [413, p. 7].

More modern ideas of privacy broaden this conceptualisation. The right to control what happens to your personal information and your personal space is put forward by Moore, who describes privacy as the "*control over access to oneself and information about oneself*" [271, p. 216]. Irwin Altman's opposing forces conception of privacy: as a tension between opening and closing a personal boundary to others with desired levels of engagement dynamically changing over time for any given individual, adds a further dimension to privacy understanding [9]. It may be considered as the process of letting others in or keeping them out, a way of controlling access with boundaries.

Primarily, at the centre of all of these definitions is the idea of protecting one's self. However, with today's technology and use of databases, such as for customer relationship management or online media, managing boundaries, controlling or even knowing who can access your information is incredibly difficult. Hence, understanding privacy through possible harms may be of greater relevance. Solove states *"We should conceptualise privacy by focusing on the specific types of disruption and the specific activities disrupted rather than looking for the common denominator that links all of them"* [366, p. 45] and asks for a ground-up approach to understanding privacy.

Solove has outlined the difficulty in defining privacy and suggests rethinking the concept of privacy, suggesting there are multiple yet related forms. He provides a taxonomy for privacy infringing activities and violations [365]. Solove also puts forward that privacy is shaped by social norms and assists in the regulation of social relationships.

This idea of privacy as related to social norms is also explored by Helen Nissenbaum, with her "Contextual Integrity" theory of privacy norms [286]. Nissenbaum suggests that privacy expectations are mainly determined by social norms of information flow for specific contexts. It is not a complete definition of privacy per se but a normative framework for understanding information flows and privacy expectations, with four fundamental constructs: informational norms, appropriateness, roles and principles of transmission. Contexts are understood as structured settings, each of which have their own behavioural expectations and roles. For example, in hospitals, shopping centres or schools, there are different expectations of privacy. Social norms also vary across cultures, and cultural identities may shape privacy expectations, hence there may be different privacy expectations for different cultures in specific contexts.

This idea of privacy expectations being based on specific contexts is highly relevant

for this study of social robots in public spaces. If we are to create a social robot application that collects information from people, we need to understand peoples' expectations of confidentiality and discretion regarding the information collection and use within the specific context. Essential to our understanding are people's reasons for sharing and the context in which they share it at the time.

If we are to break the contextual integrity, *i.e.* the expectation of privacy norms in an interaction, it may have a detrimental effect on people's feelings towards the robot and hence limit creating a positive UX. Hence it may be said that there is a value and importance in respecting privacy norms for positively experienced HRI.

The value placed on privacy I now cover in the next section.

2.6.2 Value and Importance of Privacy

Privacy is important as it may be considered necessary for an individual's wellbeing and ability to flourish [272] and it has psychological and sociological dimensions that are necessary for personal development and stable relationships [252]. A few uphold the view of privacy as being vital for relationships. Fried proposes that privacy is essential for one to form intimate relations with others and define oneself as an individual [134]. Schoeman continues this idea of privacy being required for intimacy in relationships with others and also the development of one's personality and inner self [342]. Rachels goes further and suggests privacy allows us to control our relations with others in a variety of social relationships, not just intimate ones [306]. Controlling access and information enables us to vary behaviour and activity with others, thereby controlling our social relationships with different people. Rachels also argues privacy is valuable because it is necessary to protect our assets and interests, and it protects us from embarrassment or detrimental consequences from information leaks.

Privacy is also viewed as not just being vital to individuals but also to societies. "*the value of privacy should be understood in terms of its contribution to society*" [365, p. 98]. Privacy has an essential social value [97], and it may be understood as being constructed by the norms of society [365]. Indeed Solove puts forward that privacy is an important component of any community that wishes to thrive, as it allows a zone of freedom away from community infringement and prevents stifling of people's freedoms and welfare. Essentially, it may be thought of as a necessary component of a liberal democratic society [97].

Nevertheless, privacy is also a balancing act—that of the aims of the broader community balanced against an individual's compatible desires. There are also times when

protecting privacy enables abuse, such as in domestic violence cases [249]. Solove suggests that we balance the value of privacy and the conflicting interests for each particular situation and address it by procedures of oversight and limitation.

Privacy is considered so important that the right to privacy is listed in the 1948 Universal Declaration of Human Rights, Act 12. *"No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation. Everyone has the right to the protection of the law against such interference or attacks."* Signed by over one hundred and fifty countries, the Universal Declaration of Human Rights provides an agreed expression of fundamental values shared across cultures, the base from which social norms may be followed, or not, regarding different cultures emphasis on privacy. In fact, in recent times the European Union has implemented this spirit of privacy protection with the law, with the General Data Protection Regulation (GDPR) act, the aim of which is to give individuals control over their personal data, in recognition of the massive collection and processing of personal data possible with today's technologies. An older but now increasingly prevalent view is that of Bloustein, describing privacy as essential to human dignity and that invasions of privacy are, in fact, affronts to human dignity [34].

2.6.3 Consumer Privacy

For this dissertation, the focus is on social robots that interact with people in public spaces. The applications for which the social robot may be used include providing services that involve collecting people's personal information, such as name, gender, or biometric data. When an organisation or business collects personal information, it is subject to privacy regulation. Hence I also look to *consumer privacy* in these studies. Consumer privacy law is intended to protect customer's personal information. The inability of consumers to be able to know where, for what, and to whom, their digital data goes has led to many outcries by the public, with Facebook being a prime example of this [187].

The internet, big data, massive use of online social networks where users share personal information and feelings, and mobile apps that track users every move has led to worldwide awareness of the need to protect privacy and look after the user. The ability of businesses to bring together or sell disparate pieces of information that can be used to create a profile of a customer means that the average user is no longer able to control what information is known about them and to whom. A tremendous body of work exists investigating privacy and internet technologies and a review of this is outside the scope

of this report. However, a couple of vital points, relevant to social robots in public spaces, to pull out of the internet technologies' research, are the following:

- Social relationships and place are significant factors in user expectations of privacy [102].
- Users are generally unaware of how their communications and data can be accessed, and the implications for their privacy [219, 245].

Whether these issues from the digital world translate to HRI is still to be discovered. However, the physical and social aspects of social robots may also increase the ways in which privacy can be impacted. Ryan Calo [55] has outlined three suggested ways in which social robots can impact privacy, and I present these in the following section.

2.7 Social Robots and Privacy

Social robots present their own unique challenges for privacy. Robots can be autonomous, mobile and sharing public or private space such as shopping malls or homes, with users. Complex sensors allow multiple methods for recording and assessing data, and these cannot always be seen or identified on the robot. Finally, the actual social interaction between human and robot usually involves anthropomorphising of the robot, and this may engender users to reveal unsolicited personal information [55]. Calo [55] identifies the impacts of privacy in social robotics and separates considerations into three categories:

1. Direct surveillance
2. Increased access
3. Social meaning

Direct surveillance is the capability of the robot to record, analyse and monitor interaction with a user. This is the most obvious of the impacts on privacy. Robots have many sensors to allow them to navigate their way and interact with humans autonomously. Facial detection and facial recognition are standard features in social robots. This surveillance category can also be extended to include not just direct monitoring of user interaction but also the monitoring of passers by or visitors.

Increased access is the introduction of social robots into previously private areas such as the home. This has implications regarding manufacturer's use of collected data and hijacking by hackers.

Social meaning is the dimension most relevant to this dissertation. Humans are ingrained to treat robots as if they are social actors and interact using social norms, regardless of whether they know, intellectually, that robots are just machines [311, 433]. Calo suggests that this, in turn, causes human behaviour to change in various ways due to the sense of being observed and evaluated (by the robot). The example given is the robot in the home, interrupting solitude, a necessary aspect of privacy. The more human-like a robot, the greater the anthropomorphising that occurs, the greater the sense of a social entity, and the possible sense of being evaluated that could occur.

Further to these, if a human reacts to a social robot by following social norms, there is a possibility that the social norms for expectations of privacy also apply. Hence if a robot was to receive personal information in a conversational exchange, there might be the expectation that the information goes no further. However, robots are data collection devices and, unless otherwise purposefully designed, the information they collect may be transmitted or shared with other recipients and used in other contexts, outside the situational context in which the information was given.

Additionally, information collected by the robot may also be used to inform the robot's social behaviour in an interaction, and this may also be an example where social norms dictate privacy expectations. An example of this and the importance of meeting the social norm for expectations of privacy can be found in the hotel study conducted by Chung and Cakmak [70] from Section 2.3. In Chung and Cakmak's study, they stated their goal of protecting consumers privacy. However, the behaviour of the robot did not meet the expected social norms for the information the robot was receiving and the stated manner in which it would be shared.

An interesting phenomenon has been described to occur when people interact with technology that involves the exchange of personal information, sometimes referred to as the 'privacy paradox'. This is when the stated privacy intentions of a person regarding the disclosure of their personal information are in direct opposition to their actual behaviour regarding personal information disclosure [288].

Multiple studies that include investigation of the privacy paradox exist, for example, in social media [240, 301], smartphones [371] and online [16]. Investigations have also recently been reported in social robotics studies by Lutz and Tamó-Larrieux [248], finding privacy concerns are usurped by the perceived benefits of the social robot. However, using Nissenbaum's theory of contextual integrity, it is possible to understand that it may not be such a paradox. It may instead be the situated context of the information flows and privacy expectations involved, that lead people to share information that they would

not otherwise have shared in different contexts. Given that users are unable to assess a robot's capabilities accurately [220, 295], this privacy paradox may appear to seemingly exist for interactions with social robots, as users may have privacy expectations inline with the social norms of a situation for their personal information. However, privacy considerations of users regarding social robots are still to be understood. Hence, I explore the relatively new field of Privacy Sensitive robotics in the next section.

2.7.1 Privacy Sensitive Robotics

The term privacy-sensitive robotics is concerned with personal privacy in HRI. Privacy sensitive robotics can be thought of as a subset of HRI that explores users' privacy considerations. This includes work on both understanding privacy in HRI and protecting privacy in HRI [326]. Privacy sensitive robotics is a new field with a growing significance due to the greater worldwide interest in privacy, and this growing interest can be seen particularly in social robot research [247]. With this work, I focus on protecting privacy in HRI and hence look to designing for privacy, or privacy-sensitive design, as a way to do this.

2.7.2 Privacy Sensitive Design for Social HRI

In the perspective of a privacy-sensitive design approach, users' privacy considerations are an essential element in designing the considered system [326]. Privacy-by-Design (PbD), is one approach for designing privacy into social robotics that has been suggested [326] due to its appropriateness of use, and there is a common acknowledgement of significance by Canada, EU, USA and Japan lawmakers [188]. A Privacy-by-Design approach ensures privacy protections are built by default into a system from the beginning and this may also be considered good business practice [415]. Incorporating a PbD approach ensures that a user need not always be mindful of protecting their privacy in an interaction. This is especially important with the consideration of the effects of a user's possible treating of the robot as a social entity, as described in previous sections in this review. There are seven foundational principles of PbD [62]:

1. *Proactive not Reactive, Preventative not Remedial*

2. *Privacy as the Default Setting*

3. *Privacy Embedded into Design*

4. *Full Functionality — Positive-sum not Zero-sum*

5. *End-to-End Security — Full Lifecycle Protection*

6. *Visibility and Transparency — Keep it Open*

7. *Respect for User Privacy — Keep it Open*

The principle initially focused on in this research is that of number 6., transparency, the components of which are described by Mittelstadt *et al.*: "*The primary components of transparency are accessibility and comprehensibility of information*" [270, p. 6] Social robots are designed to process personal information yet provide little, if any, transparency around this occurring in an interaction. Hence, in any application, transparency has to be explicitly and purposefully designed.

The idea of "transparency by design" has been put forward as a method of fair data handling practice [339] and the need for transparency in data collection is a requirement of the European Union's General Data Protection Regulation (GDPR). Transparency is linked to trust, and acceptance of, robots [336, 421] and is an essential factor to consider in designing a human-robot interaction [203]. Vital to discover is how much visibility of information is the right amount, preventing cognitive overload [320], for both privacy considerations and positive user experience.

Design methodologies for privacy considerations in social robot application design, based on real world use cases are, however, still not apparent. Recent guidelines provided for social robots and transparency by Felzmann *et al.* outline specifying of the amount of transparency based on user groups and relevant knowledge [117]. However, the detail is not provided as to how the transparency communication provided to users will affect their experience with the robot, nor have they been tested with a real world use case. The role of transparency in affecting user's privacy expectations and subsequent user experience with a social robot is hence an important area to further explore in social robot application design and one which I investigate in Chapter 5.

The Privacy-by-Design approach has also been proposed recently in designing for privacy for robots by Heuer *et al.*[173] as a way to mesh privacy engineering with robotics development. Heuer *et al.* suggests using the Privacy-by-Design approach and Risk management, using the cycles of risk identification, risk analysis and risk mitigation. The seven types of privacy by Finn *et al.*[120] are used for the risk identification. The approach describes designing privacy for robot functionality, *e.g.* sensor choice, using a hypothetical use case. This approach has merit, however whether it can be translated to

real world, social robot application design is not known. Hence, using the seven types of privacy approach is investigated in Chapter 6.

What is clear from the literature is that privacy design for social robots is still a fledgling area, requiring methodologies and best practices to still be determined. Unknown is how to protect privacy regarding social robots in public spaces. While privacy-sensitive robotics puts users' privacy considerations as an essential element in designing the considered system [326], the methodology for how to do this effectively, is also not yet known.

Furthermore, literature in social robotics that combines designing the user experience and designing for privacy could not be found.

2.8 Conclusion

What is apparent, is that vital for HRI design is to consider the physical environment of use and the task / social context, with users. Including this situated context greatly increases the dimensionality of the research at hand. Furthermore, as is clear from the literature, methods, or guidelines which account for situated contexts, such as placing robots in public spaces, are limited. When social robots are placed in public spaces, any application should be carefully designed to avoid or reduce people's feelings of concern, particularly privacy concern, or annoyance. A good user experience accounting for privacy issues should, in fact, be purposefully designed. This care should be taken to avoid a negative impact on the ambience of the public space and subsequent societal impact. These issues cannot be ignored if people are to accept and use the robot. Methods and design principles or guidelines that specifically cater to social robots in public spaces are still needed to be added to the literature. As discovered from the review, the methods missing from the HRI literature for social robot applications are:

- HRI design methods for discovering and creating viable, socially responsible use cases (applications) for public spaces
- HRI design methods that include a full, iterative, UX process of analysis, design, implementation, and evaluation for public spaces
- HRI design methods that include privacy considerations for public spaces
- HRI design guidelines or principles that specifically incorporate both UX and privacy for public spaces

Consequently, by attempting to address these gaps, this dissertation will further explore the field and expand the research possibilities for social robots in public spaces.

CHAPTER 3

RESEARCH METHODOLOGY

"Until we enter the field, we do not know what questions to ask or how to ask them." Steven Taylor, Robert Bogdan and Marjorie DeVault [376, p. 30]

This research has a dual contribution of providing further investigation towards design theory for Human-Robot Interaction (HRI) and practical application for professional practice. Herbert Simon describes design as *"...courses of action aimed at changing existing situations into preferred ones."* [357, p. 111]. This description is most appropriate for my chosen research involving incorporating privacy and UX design into design principles for HRI, moving to a preferred situation of robot applications in public spaces that are designed to be socially responsible. This perspective aligns with the perspective reported by Research through Design (RtD), from the HCI (Human-Computer Interaction) research field, with research focused on the goal of improving society as a whole [430, 431]. This research project is not a case of what *could* we make but what *should* we make.

As previously stated, the primary purpose of this research is to provide a framework, including design principles, for commercial social robotic platforms. The framework is to assist the discovery, identification and design of socially responsible social robot applications that meet genuine needs of real people in specific environments. Testing and implementing the designed application in the desired environment to measure its success is also a part of this process. Human-robot interaction is still a relatively new

discipline, and the field is still to be explored. As such, no design guidelines for social robot applications that expressly incorporate UX and privacy yet exist and there is no comprehensive guide for implementing said applications.

Research design is the entire process of research from conceptualising and identifying a problem to writing research questions, collecting data, analysis, interpretation and report writing [376]. This chapter describes the research design approach, outlines the studies undertaken, how the insights from the studies were used, and the integration of the studies to answer and update the research questions and final framework. Creswells' framework for research [79], which consists of the interacting components of philosophy, research designs and specific methods, is used to summarise my research approach below.

Research Approach: Mixed Methods

Paradigm / Worldview: Pragmatical with a critical realist philosophy

Research Design (Strategy of Inquiry): Action Design Research (ADR)

Specific Research Methods: Open-ended and closed questions; pre-determined and emerging methods; multiple forms of data: performance data, observation data, interview data; statistical and text analysis; themes and statistical interpretations

3.1 Research Approach: Mixed Methods

This research has been approached using mixed methods research, a combination of qualitative and quantitative methods.

To aid this work, we need a detailed understanding of the field that includes the complex inter-dependent factors involved and the interaction of said factors. Qualitative design is especially suited to this type of exploratory research as it involves talking directly with people to understand their perspective, which enables confidence in the conclusions and also discovers phenomena that may not be found in the literature [80]. The intention with this work is to go beyond general design requirements, typically generated from qualitative design studies, and to iteratively test application designs using the proposed framework for HRI in the wild.

Interactions between people are difficult to represent and encapsulate with quantitative measures, and statistical analysis does not cover the whole story and may not be sensitive to individual differences [80]. Indeed this may also be considered to be the

case between people and robots. Consequently, qualitative research is a vital method to explore HRI. Reliance on quantitative studies as the only method for HRI research would limit usefulness, as stated by Šabanović *et al.*:*"The contextual nature of social interaction precludes reliance on quantitative measures of human-robot social interaction alone, as this would lead to the systematic exclusion of evaluations of phenomena that are not easily amenable to quantification."* [330, p. 577]

Qualitative design involves constructing and reconstructing the research design, as new knowledge or relationships are conceptualised [261]. In contrast to other views of research design, the research questions are not fixed at the start of the study. Research questions may be modified or expanded upon as a result of what has been learned in the study. Additionally, the design does not have a predetermined starting point, nor a fixed sequence of steps to follow, instead, it is an interactive and interconnected structure that is influenced by the context in which it is operating. As such, the research design approach taken for this dissertation could be thought of as a qualitative approach to mixed methods design [375].

The main idea with this research is to learn from participants and understand their perspective for HRI. Then use these learnings to inform the identification of factors that are of importance in our stated interest areas of social robot applications, privacy and UX, for creating socially responsible social robot applications. Qualitative research has the following characteristics, as outlined by Creswell *et al.* [80]:

1. *Emergent Design*. The initial plan of research is determined with an understanding that any part of the research process may change, shift or be removed from the process once fieldwork has been started—understanding that each contribution depends on the preceding.

2. *Natural settings*. Qualitative research involves getting out into the field and talking, in person face-to-face, to people. Observing how people act and behave within the situated context.

3. *Reflexivity*. The experience of the researcher, how their experience informs their interpretation of the research and what they hope to gain from the research is reported.

4. *Complex reasoning*. Inductive and deductive logic is used throughout the process.

5. *Multiple Methods*. Gathering of multiple forms of data, that includes interviews and observations. Avoiding reliance on one source of data and reviewing across data sources.

6. *Holistic account*. The taking of multiple perspectives and identifying of the many factors and complex interactions of these factors in different situations. Understanding that is not constrained to simple cause-and-effect relationships among factors, but the understanding of the larger picture that appears from the multiplicity of data.

Further detail, relevant to this particular project, is provided below on two of these characteristics. Reflexivity must be reported for the researcher, as per qualitative research. Natural Settings is specifically outlined as vital to not just qualitative but also HRI research.

3.1.0.1 Reflexivity

In line with the above characteristic regarding *reflexivity*, the experience that I bring to this investigation is an industry background in user experience (UX) design and development for mobile phone and web applications, supported by a Masters in Interactive Multimedia. It is with this digital technologies mindset that I have approached the field of HRI and social robots. The practice of creating social robot applications using commercial social robot platforms has parallels to mobile phone application creation for smartphones, and this is especially the case for robots that incorporate touch screen tablets in their hardware design. Differently to the mobile phone research field, and vitally missing, are guidelines for how to create viable social robot applications in a human-centred, UX focused way that protects the privacy of the user.

I hope to gain from this research an understanding of the vital differences in social robots to other similar technologies to inform a UX design process that will work specifically for social robots. Additionally required for this is an understanding of the different privacy considerations required for a social robot and how these will affect the user experience and behaviour of people in situated interactions.

3.1.0.2 Natural Settings

The importance of situating studies in the environment with robots in human social contexts has been highlighted by Šabanović *et al.*, [330] who suggests that observations of

naturally occurring social situations of human-robot interaction will assist the creation of new theoretical models of social robot behaviour. As Šabanović *et al.*, states: *"... observational analysis of the robot interacting in a real-world environment can be used to analyse how humans react to and interact with the robot; how humans interact with each other while interacting with the robot; which aspects of the robot's, and human's, actions lead to breakdowns in the interaction; and how the robot succeeds and fails to engage humans in interaction. These analyses can provide detailed quantitative and qualitative data that can be used to improve socially situated/embedded robot interactions through iterative design processes."* [330, p. 577]

3.2 Philosophical Standpoint

This design research is put forward with the philosophical position of critical realism [260], in which two perspectives are combined, that of epistemological constructivism and ontological realism (the real world exists independently to our perceptions). Essentially it is understood that it is not possible to have an entirely objective perception of reality; our understanding is basically a construction that cannot be absolute. Therefore, the conclusion to be gained from this research, and in fact the research itself, is a simplified and incomplete attempt to seize an understanding of a complex reality.

The mixed-methods approach for my research design suits this philosophical realist position, as it supports a pragmatic approach. The pragmatic approach, or pragmatism, as described by Creswell[79] is not committed to any one choice of philosophy and reality. Individual researchers have freedom of choice regarding their methods and techniques.

"The pragmatist researchers look to the what *and* how *to research based on the intended consequences—where they want to go with it."*[79]

Critical realism consists of both deductive (empirical investigation) and inductive (theory construction) processes. It relies on abductive reasoning that oscillates between induction and deduction. This perspective allows us to answer the specific research questions and provides the best chance of a credible and valid picture of reality on which to base the research. A pragmatical approach to critical realism has been adopted by others in studies using action-oriented research [167], and critical realism is seen as a complementary approach with action-oriented mixed methods research [68]. The action-oriented research design chosen for this project is described in the following section.

3.3 Research Design

Research design can be thought of as the *structural outline* for a research project. The research design outlines how all the different parts of the research come together to address the research questions.

A number of different research methodologies were investigated to determine the most suitable for the research goal of implementing social robot applications in real world settings: Action Research (AR) [67], Design Science (DS) [174], Design Thinking/UX (UX), Constructive Design Research (CDR)[214] (also sometimes referred to as Research Through Design [127]) and Action Design Research (ADR) [346]. The research methodologies were chosen for investigation due to the research project goal of producing social robot applications (artifacts) with the intention of constructing knowledge (design principles) through the action of *doing*, aiming for both practical and theoretical outcomes. The complexities of the chosen research problem are both social and technical. Quantitative and qualitative research, involving situated studies in the environment, in which robots and people will interact, as described by Šabanović and presented in Section 3.1, and participation from the potential future practitioners and end-users of the robotic platform, is proposed as the best way for an in-depth understanding of the problem context. Constructive Design Research (Research Through Design) and Action Design Research are the two most applicable methodologies and hence appropriate research designs for this research.

3.3.0.1 Constructive Design Research

Constructive Design Research (CDR) is described by Koskinen *et al.* in *Design Research through Practice* as *"design research in which construction - be it product, system, space, or media - takes center place and becomes the key means in constructing knowledge"* [214, p. 5].

The argument put forward in CDR is that knowledge is generated through the multiple activities that are involved in the construction of a design: in the planning, theoretical argumentation and application, and the production. CDR has a future-oriented, imaginative nature regarding *"how things could be"* that suits the project goal of creating a preferred future situation of social robot applications that are socially responsible. However, it is this nature that also limits its applicability for the research project. *"Constructive design researchers do not try to analyse the material world [...] nor do they see design as an exercise in rational problem solving. Rather, they imagine new realities and*

build them to see whether they work." [214, p. 42].

Additionally, according to Koskinen *et al.*, CDR researchers seldom produce something that is then commercially produced. This research project aims to provide a framework for social robot applications that have the potential to be commercially viable and work with the organisations that would implement the social robot application. Hence, while this research is very similar to CDR and shares perspectives of CDR, the research design leans more towards Action Design Research.

3.3.1 Action Design Research

Action Design Research is popular in the Information Systems field. It is described as *"a research method for generating prescriptive design knowledge through building and evaluating ensemble IT artifacts in an organizational setting"* [346, p. 40].

This inclusion of the organisational setting in the research method is critical for this research project, as it is investigating social robots in public settings, settings which may be managed by an organisation. Hence, it requires the support of the relevant organisation. Furthermore, it is understood that the organisation is involved in the shaping of the artifact. While this research project does not follow the exact ADR process as circumstances and opportunities differ, it is considered to provide the most applicable approach through which to view and inspire the research.

The ADR method as put forward by Sein *et al.* [346] is described as the following:

ADR comprises four stages, each of which are grounded by principles that describe the underlying assumptions. The four stages are:

1. Problem Formulation
2. Building, Intervention and Evaluation
3. Reflection and Learning
4. Formalisation of Learning

Note that the four stages are not enacted within a waterfall sequence but are cyclical and re-iterative. The stages and the seven governing principles are displayed in Figure 3.1.

Action Design Research is particularly appropriate to be used and adapted for this research due to the stages and principles it draws on, described in the following.

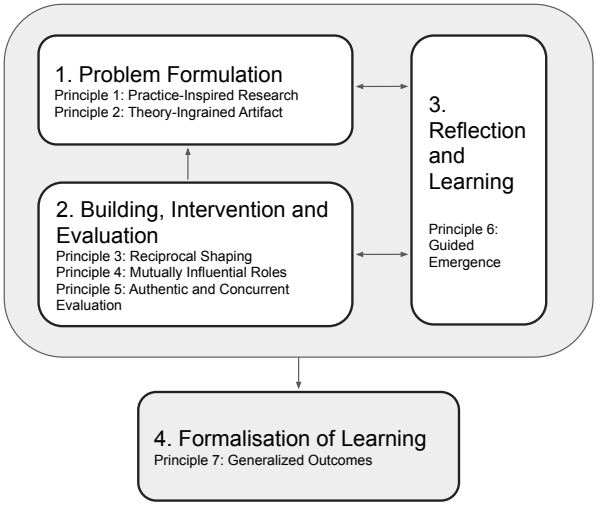


Figure 3.1: The stages and principles of Action Design Research, adapted from Sein *et al.* [346, p. 41]

3.3.1.1 Stage One *Problem Formulation*

The formulation of the problem may be assisted by empirical research, a problem perceived in practice, prior research, stakeholders (researchers, practitioners, end-users) and current technologies. This stage combines the principles of practice-inspired research and theory-ingrained artifact.

1. Practice-inspired research involves viewing problems from the field as knowledge-creation opportunities. The purpose is not to solve the specifically identified problem but instead to generate knowledge that can be applied to the *class* of problems that the issue represents.

2. Theory-ingrained artifacts specifies the use of theory to create the artifact. The theory used can be generalised and abstract. The idea is that *"the action design researcher actively inscribes theoretical elements in the ensemble artifact "*[346, p. 41] and this allows the theory to be expressed in a way that is socially recognised.

3.3.1.2 Stage Two *Building, Intervention, and Evaluation*(BIE)

Stage Two builds on the theoretical premises and problem identification from Stage One to create an initial artifact design (in this project's case: social robot application). The

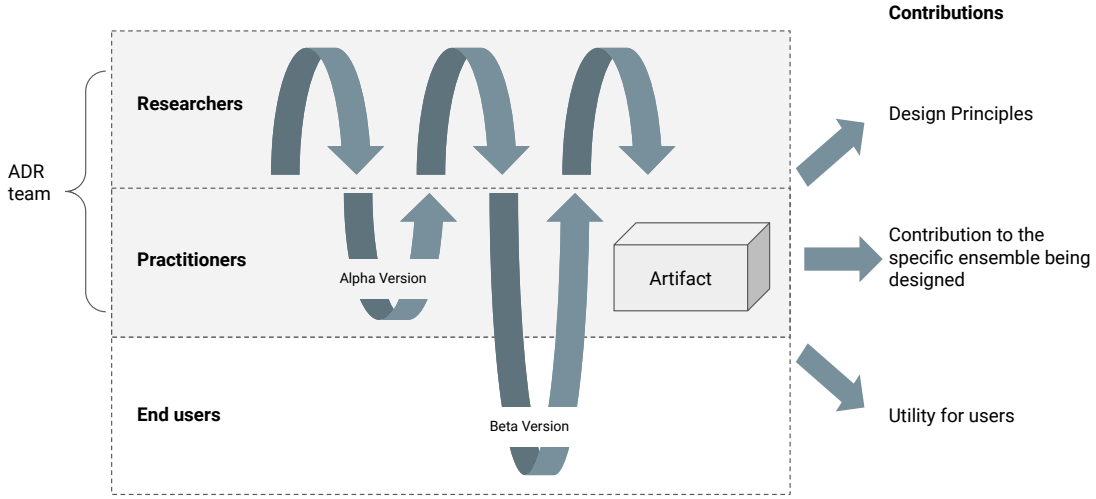


Figure 3.2: Schema for IT-dominant BIE, adapted from Sein *et al.* [346, p. 42]

initial artifact is then reshaped by cycling through the implementation of the artifact within the chosen environment. During this stage, the artifact is continually evaluated, and the design principles are articulated for the class of problem chosen. This stage is described as having two design continuum endpoints: Information Technology (IT)-dominant Building, Intervention, and Evaluation (BIE) and Organisation-dominant BIE. IT-dominant is related to innovative technological design; Organisation-dominant is related to effecting change within the organisation. For this stage, the most applicable is IT-dominant BIE, which can be viewed in Figure 3.2

Stage Two involves the three principles (as shown in Figure 3.1) of Reciprocal Shaping, Mutually Influential Roles, and Authentic and Concurrent Evaluation.

3. Reciprocal Shaping This is the influence the IT domain and the organisational context have on each other. The ADR team (researchers and practitioners) engages in an iterative process that involves interpretation of the environment and selecting and shaping the design construct.

4. Mutually Influential Roles This principle emphasises how the multiple participants in the project, both researchers, with knowledge of theory and technology, and practitioners, with work practices, learn from each other and share their specialised knowledge.

5. Authentic and Concurrent Evaluation The evaluation process is never separated

from the building and intervention; it is an integral component. Evaluation must be allowed to occur spontaneously in the environment, authenticity being more critical than a controlled setting. Evaluation can be either formative or summative, and contribute to the refinement of the artifact.

3.3.1.3 Stage Three *Reflection and Learning*

Stage Three is run continuously and in parallel with the first two stages. It moves the research design from that of solving a specific problem to that of solving a class of problem. This stage involves conscious reflection on the emerging ensemble and identification of the knowledge contribution from the increasing understanding of the evaluated artifact. The principle of Guided Emergence supports this stage.

6. Guided Emergence The interaction between the initial design and the implementation in the target setting with evaluation of the artifact's use and perception by participants, allows a continuously evolving and reworking of the emerging artifact.

3.3.1.4 Stage Four *Formalisation of Learning*

This final stage formalises the learning into a general solution for the identified class of field problems. The outcome is design principles and the possible refinement of the contributing theories from Stage One. The design principles are fully formulated and articulated in this stage, crystallising their identification and refinement from throughout the reflection and learning stage. The principle of Generalised Outcomes supports this stage.

7. Generalised Outcomes This principle highlights the generalisability of the solutions to the identified problem and is a critical component of action design research. It is the move from *"specific-and unique to generic-and-abstract"* [346, p. 45].

It is an inductive step that connects the generalised design principles to the class of problems and solutions. It is the capturing of the knowledge from the process of building solutions for a given domain and then generalising this knowledge to enable its use.

3.4 Research Design Outline

Rodney Brooks famously put forward that by 2020 robots would be pervasive throughout our lives [47]. However, this clearly hasn't happened. This led to speculation as to what ways robots could be used in today's society. Operationalised, commercial applications of

social robots were yet to be deployed in Australian society, and limited examples existed overseas. As such, a research opportunity existed to explore the potential applications of commercial social robots in the field and how this would impact Australian society. A challenging yet vital component of HRI research is conducting field research with robots, observing the situated dynamics of human and robot interactions "in the wild" [330]. Forming partnerships with organisations interested in social robot technologies and able to support in the wild studies in public settings increases the research opportunities available.

The University of Technology Sydney (UTS) Innovation and Enterprise Research Lab partnered with the Commonwealth Bank of Australia (CBA) in 2016 to explore the potential applications and impacts of social robotics and Artificial Intelligence (AI) on the lives of people and industries across Australia. The partnership was formed with the stated express goal: *"This corporate-academic partnership is exploring the opportunities and limitations of human-robot interaction, and pursuing commercial applications of social robotics across a number of industries in Australia."* [13]

This partnership enabled this research project to begin. The research partnership provided an industry run innovation lab and potential industry clients interested in social robot applications. Most importantly, the research partnership provided a commercial social robot for use by researchers, a PAL REEM humanoid service robot, Figure 3.3. It should be noted that the research partnership catered to many different research goals and researchers, the research project for this dissertation was just one of many. The partnership comprised of a multidisciplinary team of students and professionals from various backgrounds and skill levels. The team involved in this research project included UTS researchers, a Senior Project Manager, Senior Engineer, PhD students and Post Doc researchers, and employees of the CBA Innovation lab (hereafter referred to as practitioners). The initial research question began with *"What are the potential commercial applications of social robots in public settings?"* This triggered the first part of this research: problem formulation.

An initial literature review revealed a deficit of feasible real world use cases of social robot applications and limited resources available for organisations to easily understand how to deploy robots that interacted with people (social robots). Furthermore, there were only disparate design principles on how social robots should be implemented or used. Additionally, it quickly became apparent that legal considerations, such as privacy, were yet to be of interest to research.

Designing social robot applications with privacy considerations in mind ultimately

determines the experience of how a robot behaves and interacts with people in the real world. Without designing robot applications in this manner puts in doubt the real world value of HRI studies for social robot applications in public settings. The behaviours, interactions and overall experience may be different when these considerations are not included. Compliance with privacy legislation is of vital interest to any business wishing to avoid negative press and fines for privacy misconduct. Hence, this research specifically aims to create social robot applications that are acceptable to organisations because of their compliance with privacy legislation and proven social responsibility, providing genuine real world value.

To further explore the research opportunity in this area, two main experiments were undertaken to assist in problem formulation. These then informed the three central design studies considered as the BIE stage. The purpose of the design studies was to extract principles for design. Each study contributed towards the learning and reflection stage, which identified the best practice and design principles for refinement in the final formalisation stage. The full outline of the research can be seen in Figure 3.3. Additionally, each study enabled articulation, further re-framing and refinement of research questions. The specific methods used for each study are described in the following section.

3.5 Methods: Studies and Experiments

As stated by Maxcy, it is *"perfectly logical for researchers to select and use differing methods, mixing them as they see the need, applying their findings to a reality that is at once plural and unknown"* [259, p. 59].

To fulfil the goal of creating design principles for effective deployment of socially responsible social robot applications for public spaces, across contexts, required studies in different public settings. The term design studies are sometimes used in this dissertation, to frame these studies as explorations of theory and experimentation, providing design insights and approaches. The design studies informed the design and construction of a scaffold for both application prototyping and the desired design process, enabling progressive exploration and re-framing of the study hypotheses and overall research questions. Different methods were applied, depending on the type of experiment or design study conducted. The following provides an overview of the five primary studies undertaken. The context, content and purpose of the experimentation, and the papers contributed to from the study, are listed. Also provided is Figure 3.4, a description of each study or experiment and the applied methods, allowing a further understanding of

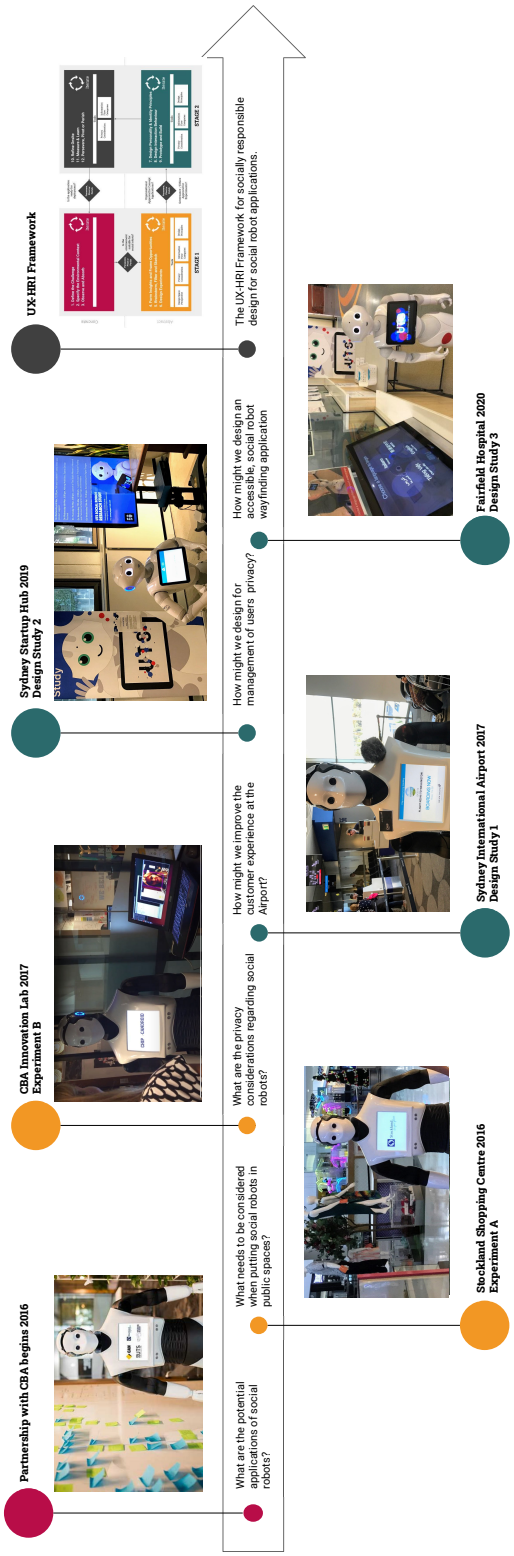


Figure 3.3: The research design of this project

EXPERIMENT	CONTEXT	STAGE	MY ROLE	CONTRIBUTION	DESCRIPTION
[Experiment_A] Studies In the Wild - Applications and Challenges	Field - Stockland Shopping Centre	Problem Formulation: Knowledge generation from practice with theory ingrained artifact	Researcher Facilitator	[Paper_1] Would you like to sample? robot engagement in a shopping centre	Begins the investigation into applications for commercial social robots to conceptualise and identfy the research opportunity. Compares human vs robot. Serves as a basis for understanding the challenges of application design & development, appropriateness, and implementation.
[Experiment_B] Privacy and its effect on UX in HRI	Lab - CBA Innovation Lab	Problem Formulation: Knowledge expansion with theory inspired postulate	Researcher Interaction Designer	[Paper_2] Embodiment, privacy and social robots: May i remember you? [Paper_3] Be more transparent and users will like you: A robot privacy and user experience design experiment.	Investigates the effects of embodiment (social roobot vs kiosk) and transparency (Privacy-by-Design principle) on privacy considerations and user experience
[Design Study_1] Designing the UX for HRI	Field - Sydney International Airport	Building, Intervention, Evaluation	Researcher	[Paper_4] Design methodology for the ux of hri: A field study of a commercial social robot at an airport.	Covered the process of identfying, designing, developing and implementing a social robot application for a specific organisation.
[Design Study_2] Designing for Privacy in HRI	Field - Sydney Start Up Hub	Building, Intervention, Evaluation	Researcher Facilitator Interaction Designer	[Paper_5] Privacy First: Designing Responsible and Inclusive Social Robot Applications for in the Wild Studies	Extended the process from the [Design Study_1] study to specifically concentrate on privacy considerations
[Design Study_3] Designing with the UX-HRI framework for socially responsible HRI	Field - Fairfield Hospital	Building, Intervention, Evaluation	Researcher Facilitator Interaction Designer	[Paper_6] (forthcoming)	Brought together all learnings and emerging design principles regarding privacy and UX, in the UX-HRI framework

Figure 3.4: Overview of experiments and design studies of this project

the research design.

It should be noted that each experiment or study represents a chapter in this dissertation. In the experiment and study descriptions, the pronoun “we” is sometimes used, as it is representative of the work being undertaken by a team of people. The nature of conducting studies in public spaces, as described in this dissertation, is such that it would not have been possible without the significant efforts of many people, hence the use of “we”. In other areas of this dissertation, the pronoun “I” is used, to signify my personal contribution and thinking to the field.

The first experiment was vital for building both researcher and practitioner knowledge regarding deploying social robots in the wild. Until this point, all challenges were hypothetical and informed by literature, not experience.

1. *Experiment A* This experiment took place in a Stockland Shopping Centre, over two separate weekdays in December 2016. Stockland is one of Australia’s largest shopping centre property owners and specialise in shopping centres that provide whole of community initiatives [368]. Daily visitors to the shopping centres number

in the thousands. The chosen application replicated a human social interaction task with robot substitution in place of human, *i.e.* robot-human interaction instead of human-human interaction. The task was to promote samples to customers in the shopping centre. The initial research question asked *"To what extent can a robot perform a task requiring social engagement as well as a human?"*

Methods were empirical and involved counting the number of samples given away during social interaction with a robot compared to social interaction with a human.

The idea to trial a social robot application in the field is in line with the ADR principle of practice-based research, viewing the field as an area for knowledge creation. Solving not just a specific problem but viewing the activity as a way to explore and generate knowledge, and apply it to the class of problems. Learnings from this phase were documented, and reflections lead to new, further advanced research questions. This phase of the research is described in full detail in Chapter 4.

2. *Experiment B* This experiment took place in the Commonwealth Bank of Australia (CBA) Innovation Lab [75] in early 2017. The Innovation Lab provides a testbed for testing of groundbreaking ideas for start-ups, corporates and the wider community. It is the ideal location for social robot research due to its constant stream of visitors looking to conduct or take part in usability testing and experiments. The experiment considered the privacy-sensitive design of a data collection system for face identification with the effects of embodiment and transparency on the user experience.

   Methods for data collection included online questionnaires and physical interaction with a robot which included specific tasks involving data collection and participant interviews.

   Online questionnaires are a standard method for gathering information from users regarding their opinion on social robots [118, 207]. Online questionnaires make it relatively easy to solicit participants and collect their data, and requires minimal effort from participants. The online questionnaire informed the lab experiment, which consisted of treatment groups with a between-participant design. Experimental research that involves control and treatment groups to understand a factor affecting, say user perception, is a standard approach used by many in the HRI field [161, 208, 295].

This experiment was crucial in understanding how privacy-sensitive design would change the user experience of interacting with a social robot. Social robot application design that meets legal considerations are invaluable to organisations and those looking to implement real world deployments of social robots. Furthermore, research involving User Experience (UX), a standard business expectation and area of interest to Human-Computer Interaction (HCI) and Mobile HCI, is only just starting to gain traction in the HRI field. The learnings and reflection from this experiment are provided in Chapter 5.

3. *Design Study 1* This first design study begins the second stage of the ADR inspired process: Building, Intervention and Evaluation. The design study involved the creation of a prototype social robot application, deployed and used in the real world at Sydney International Airport in mid 2017. Sydney International Airport is one of the busiest airports in Australia. It sees an average of 150,000 visitors a day [373]. An international airline provider partnered with the CBA Innovation Lab to explore how social robots could assist customers and enhance the customer experience at the airport [74]. The CBA PAL REEM humanoid service robot was programmed with several capabilities for three applications. The applications were created based on the learnings discovered during the previous studies, the current theory regarding HRI, and Lean UX Startup design and development. Involved in this Design Study were the CBA and UTS researchers, as well as the airline employees, comprising of a wide range of professions.

   The methods involved in this design study included need-finding, workshops, thematic analysis, think aloud, role play, online questionnaires, application metrics and constant micro evaluation of the application throughout the iterative design and development process.

   The commercial sensitivity of this study prevented disclosure of specific results. However, the learnings from the process undertaken for this study provided the majority of the design principles used for the UX-HRI framework. The detail of this study, learnings and reflection are found in Chapter 7.

4. *Design Study 2* This second design study focused on the areas insufficiently covered by the first design study, namely *"How to manage users privacy?"*. This study involved a reduced team of only UTS researchers, due to the original robot platform no longer being available from the initial CBA partner organisation. The robot

platform used for this study was a Pepper [1] robot from Softbank robotics. This study instead took place with a government-run organisation named JobsforNSW [2], at Sydney Startup Hub in early 2019. Sydney Startup Hub is the location for Start-ups in Sydney, Australia [194] with monetary support from larger corporations for innovative projects. Patrons of this establishment are typically tech-savvy and professional entrepreneurs. The location has approximately 1100 people registered in the community and numerous events that attract visitors. The study initially intended to release a full-scale application; however, due to the reduced team size, the application instead focused on the first step of a shared system, user registration and login.

Methods in this design study included need-finding, workshops, thematic analysis, think aloud, role play, online questionnaires, application metrics and constant micro evaluation of the application throughout the iterative design and development process. Differently to the previous design study, this study also included onsite real-time enhancements of the robot application in response to identified constraints during the initial functionality test. This on-the-fly development and adaptation of Pepper onsite was based on direct learning from the previous design study.

Learnings from this study guided inclusive and best practice design. The detail and reflections from this study are in Chapter 8.

5. *Design Study 3* This final design study took place in partnership with South Western Sydney Local Health District (SWSLHD) in early 2020. SWSLHD incorporates 7 hospitals and is the largest hospital district in Sydney, Australia, covering a population of approximately 820,000 people [372]. The robot used in this study was the Pepper robot, and the goal of the study was to improve the experience of people in the Fairfield Hospital environment. The application for this environment had the essential requirements of inclusivity and accessibility, building on the learnings from Design Study 2. Additionally, the study had the added complexity of Hospital Ethics submissions.

   Methods included in this design study followed the previous two studies. Need finding, workshops, thematic analysis, think aloud, role play, initial functionality testing with on-the-fly development and online questionnaires, application metrics

[1] https://www.softbankrobotics.com/emea/index.php/en/pepper
[2] https://www.jobsfornsw.com.au/

and constant micro evaluation of the application throughout the iterative design and development process.

This study was paused due to the COVID19 pandemic; however, the initial BIE stage has been completed. The learnings and reflection from this study provided the basis for the final components of the design principles. These have been detailed in Chapter 9.

Once all experiments and design studies were completed the final stage of formalisation of learning occurred, resulting in the design principles, which form an essential component of the UX-HRI framework. This involved integrating and bringing together the learnings and reflections from all stages of the project. The final design principles, design space perspective and design process for socially responsible social robot applications are provided in Chapter 10

3.5.0.1 Ethics and Risk Considerations

Understanding how people will interact with social robots requires human participation, to take part in human-robot interactions, undertake task actions with robots and complete surveys or interviews.

The locations in which research has taken place provide a large pool of potential participants for HRI studies. Collecting data for research publications requires approval by the University Human Research Ethics Committee (HREC). Additionally, the organisations in which studies are undertaken require approval from internal governance boards, or similiar, due to the involvement with potential customers and the subsequent risk to their revenue.

Research in public spaces comes with several challenges, as human social interactions are unstructured and unscripted. To enable informed consent in open public spaces for robot interactions requires signposting of the area in which the robot is situated to inform potential participants that interaction with the robot implies consent to their participation in the study. The risk to this approach is that people's behaviour will change, due to the perception of being involved in a research study. However, research cannot occur without this information being provided to participants. Hence all findings from studies in public spaces are understood to be only a realistic approximation of real world interactions, which is incidentally also inline with our philosophical perspective, as previously outlined.

Part II

Problem Formulation

CHAPTER 4

SOCIAL ROBOTS IN PUBLIC SPACES

"Rather than taking a design perspective of imitating human-to-human interactions with literal substitutions carried out by the robot, robotics design should engage in engineering alternatives to how humans accomplish particular goals." Blanca Miller and David Feil-Seifer [268, p. 8]

Chapter Summary *Experiment A: Studies In the Wild—Applications and Challenges. Location: Stockland Shopping Centre. My Role: Researcher, Facilitator.*

Purpose *Experience the challenges implementing a social robot in a public setting and assess if a social robot is able to perform as a human-like social agent in a role requiring user engagement to be successful.*

Methodology *The robot is compared to a human in the task of promoting samples, using either a passive or an active engagement model. Success in the role is measured by the number of samples distributed.*

Findings *The robot is comparable to the human in successfully giving away samples, however active engagement for the robot was less effective than passive engagement. Greater value for organisations would be realised by considering the robot as more than just a replacement human for the task and utilising the robot's capabilities across social, physical and digital realms.*

Contributors *This chapter incorporates the work and findings produced in collaboration with: Jonathan Vitale, Suman Ojha, Mary-Anne Williams, Paul Fuller, William Judge and Xun Wang; published in the Proceedings of the 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN 2017) [384]*

In this chapter, initial efforts are made towards conceptualising and identifying the research opportunity regarding applications for commercial social robots. Presented here are the results of the empirical study considered as the first step for the problem formulation stage of Action Design Research. The study involves a social robot in a shopping mall, performing a task as would be performed by a human. Reflections on both the experiment results and the experience of deploying a social robot in the wild, followed by the areas to be investigated further are discussed.

This investigation assists in clarifying the unique experience of interacting with social robots and serves as a basis for understanding the challenges of application design and development, appropriateness, and deployment into unscripted, public environments.

For this first contribution, the research team went out "in the wild" to a shopping centre, gaining valuable experience in the challenges arising from implementing a social robot in unstructured, human-centred environments. Although being advocated since the advent of robots, reported scientific studies in the wild are relatively few, particularly in HRI [323, 330]. However, change may be observed to be occurring [131, 349].

Conducting human-robot interaction experiments in naturalistic environments like shopping centres, museums and airports encounters issues usually not encountered in experiments in the lab [204, 209, 379]. Robots that perform well in lab environments are typically not as successful in naturalistic environments which introduce more variables and a wider variety of social phenomena [330]. For example, it has been shown that the environment in which a robot is situated has a significant effect on the human-robot social interaction [334].

Furthermore, social interaction and engagement are subtle. People make snap judgements—decisions in milliseconds—that determine whether or not they like or dislike someone [107, 417]. This highlights that if a robot is to be employed in a natural environment but is tested only in labs, the robot obviously might not perform as expected in the intended application. Moreover, what is in scarce supply in research is methodologies for deployment of robots, and publications highlighting things that could go wrong [323].

Consequently, to effectively formalise the problem space I believe it is of paramount importance to firstly test a robot application "in the wild" to experience first-hand any issues. With this contribution, I progress just a little further my understanding of the uniqueness of the experience interacting with social robot technology and the difficulties to be encountered when placing social robots in public settings. This, in turn, enables further comprehension as to what additional factors should be considered in social robot

application design and enhances my understanding of the social robot application design space.

This study begins by exploring the design space of social robots, taking the perspective of social robots as social agents. This perspective is one seen in much literature [3, 88, 233, 412] and is intended to develop understanding beyond the acknowledged, well-known anthropomorphising by humans of robots. One way of approaching social robot application design for humanoid social robots is to consider parallels in human-human interaction, assessing if the mechanism of effect is the same for human-robot interaction. It is posited that if a social robot is a social agent, simulating social interaction like a human [344], and is performing a social role like a human, it should have similar effectiveness in social engagement to a human in achieving the same goal. Therefore this study compares the effectiveness of a social robot to a human in a widespread marketing promotion task requiring social engagement, that of giving away samples.

4.1 Is a social robot able to perform as a human-like social agent?

At some point in the future, a social robot will be designed and built that can adapt to any context or environment, learn or perform a task in any manner required and interact most appropriately and ethically to any situation, perhaps. This is unlikely to happen for some time. Nevertheless, much research is conducted in laboratories assuming this, or some aspect of, this future scenario. In the meanwhile, technology is now to the point where some functionalities *can* be realised. What this allows is real world implementations of social robot applications, with adaption to constraints, that can provide external validity to further research and pave the path for this future scenario. However, implementation is still not without significant challenges. Researchers and industry both struggle to manage this successfully. A stepping stone to this task can be a framework providing a set of design principles for implementation; that builds on current HRI research and theory; matches best practice in the industry; and models a direction forward that reduces harms while also further mapping the design space for social robots in society. This first study investigates a social robot in a shopping centre, as a first step towards building this framework.

Previous work concerning robots in shopping centres has established the effectiveness of robots for attracting the attention of people and potential roles for them such as shopping assistants, information guides and event promotion [204, 275, 338]. However,

just attracting attention is not enough of an achievement to fulfil a task such as a human might. Robots, in roles such as receptionists, shopping assistants and tour guides, all present with the same challenge—that of interacting with humans using social behaviour to perform their task [87, 330]. In this study, the focus is narrowed to a specific component within an interaction, that of social engagement. Engagement may be considered an essential element of a successful experience of human-robot interaction, a *"characterizing feature of the quality of the experiences with social robots"* [10, p. 2].

Engagement in HRI is commonly measured via social behaviours displayed by humans during an interaction, such as head movements, gaze, joint attention and body posture [313] as indicators of the level of engagement and also with surveys for users to confirm their engagement [353]. This study is novel in its approach by applying an application allowing the social engagement to be *measured via the performance of the robot* in a naturalistic interaction task and setting. For example, instead of the robot performing an interaction and asking users to complete an interview afterwards as to their engagement, the measurement is instead operationalised. User engagement is defined by the users' investment in physical action in the engagement process, similarly to evaluating user engagement on a website via the number of physical user actions such as click-throughs [236]. Therefore, a common task prevalent in shopping centres: that of inviting shoppers to try a sample of food was chosen. This task is regularly perceived and understood by shoppers, and it has an engagement model that involves a physical user action in the process —that of taking a sample. This method of engagement measurement minimises the impact of the experimental design on natural conditions encountered every day in a public place such as a shopping centre. This allows the discovery of additional unforeseeable phenomena and may provide many more insights for designing and developing successful commercial robot applications.

Additionally, this is an excellent example of a commercial robot application that can be of benefit for society and business, as employees carrying out the task of attracting the attention of shoppers may find it stressful [349]. Using a robot application may reduce human exposure to the stressful duties of the task.

The task measures not the *level* of engagement by shoppers, but whether the *model* for the engagement process successfully achieved the application goal of giving away samples. The approach for the task engagement model incorporated verbal and non-verbal engagement behaviours such as speech, gesturing and head movements. Additionally, the task was benchmarked by comparing a human in the same role to the robot. As such, the main objective of this study is to compare the performance of a robot and a human in

promoting food samples in a shopping centre, using different engagement models. Hence the research question for this study is:

R1 *To what extent can a robot perform a task requiring social engagement as well as a human?*

4.1.1 Related Works

The focus of this study is engagement, a topic currently not sufficiently covered by HRI experiments in public environments. Datta *et al.* [87] showed that the type of interactions executed by a robot in a shopping mall impacts on the level of engagement obtained from people. Human-robot interaction experiments in public spaces have suggested that robots making use of social cues like speech, gaze or gestures can better engage people in an interaction [273]. Similarly, the study by Sidner *et al.* [352] found that a penguin robot that performed only a few gestures proved to be more engaging than the one which did not move at all. Contrasting movement *vs* no movement, while rudimentary, highlights movement is critical, and a direction for further exploration. The ability to move is a crucial capability of robots that is explored in this study and in further contributions. Moreover, Nass and Gong [280] proposed that as the degree of social cues of a robot in a public space increased, the engagement of the people interacting also increased. These findings suggest that a robot actively interacting with people is more capable of maintaining the engagement of humans in naturalistic environments.

Prior works studying engagement in human-robot interactions [280, 352] investigate engagement by measuring social interaction cues (for example, gazing or attention) or by employing questionnaires. While of utmost importance, there is no direct analysis of engagement impacting on the real-world objective desired for the robotic platform nor application. Filling this gap is particularly beneficial to foster commercial applications of robotic platforms. Therefore, with this study, it is possible to address this gap.

4.1.2 Engagement and its role in social robotics

Engagement is commonly defined in human robot interaction studies [10, 313, 353] and for the purposes of this study, as *"the process by which individuals involved in an interaction start, maintain and end their perceived connection to one another"* [353, p. 1].

This perceived connectedness may be indicated by verbal and non-verbal behaviours such as joint attention, head and eye movements, gestures and conversational turn-taking, and physiological changes that take place during an interaction [10, 189]. As

such, the detection and measurement of these behaviours for evaluating engagement in social robotics has been a topic of great interest, and explored for more than a decade [10, 106, 266, 313, 353]. For instance, studies have investigated automatic affect recognition [59]; the effect of face tracking [353]; directed gaze and mutual facial gaze [313]; and sometimes all at once, as in the work by Anzalone *et al.* [10] where an RGB-D sensor was used to monitor body posture variation, head movements, synchronous events, imitation cues and joint attention, and integrated all the behaviours for analysis. These measurements may also be combined with a follow-up user survey on self-reported engagement levels [353].

Nevertheless, defining and measuring engagement by only these type of physiological and behavioural metrics does not have to be the only approach, especially in the case of commercial applications. Exploring the broader idea of engagement in similar fields such as Human-Computer Interaction, we find a definition that also may be appropriate for HRI:

"Engagement is a quality of user experiences with technology that is characterised by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affect" [291, p. 7].

Of these, interactivity in engagement is looked to for study. To design the methodology used in this study, inspiration is drawn from works in Human-Computer Interaction (HCI). In online services, engagement characteristics are identified as dependant on the application and experience at hand, and a viable methodology to assess user's engagement is to measure the number of physical user actions such as click-throughs [236]. Therefore, a similar methodology for human-robot interaction is proposed.

Factors which affect engagement are multitude and diverse. There are individual user factors, such as personality traits and social attitudes [189], situational and task factors [59, 77], and environmental factors, such as the distance between individuals [266], to name but a few. Hence, of supreme importance when in the wild, is to measure engagement with a specific purpose or application in mind. As such, in this study, the focus is on measuring user engagement by the successful completion of the application goal, rather than affects displayed by shoppers. While a simplistic measure, for assessing commercial applications relevant for business, it enables vital comparison of performance.

The task involves a samples promoter (hereafter referred to as the promoter) giving away samples of chocolate to interested shoppers. Both robot and human are separately trialled in the role of the promoter. For further analysis of the topic, two engagement models were compared: passive engagement and active engagement, as based on fulfilling

needs in a public space [264].

In the passive engagement model, the promoter does not move from the one spot, does not actively interact with shoppers and is behind a rope barricade, allowing shoppers to simply observe the promoter. In this setting, the robot is programmed to perform autonomous random interactions and the human acts disengaged, almost robotically, as described by Shi and colleagues [349].

In the active model, the promoter can actively engage with shoppers in a timely fashion and move around. In this second setting, the robot is teleoperated to simulate an intelligent social agent able to interact with shoppers in a timely manner directly, comparable to the human promoter. The model is illustrated in Figure 4.1. On the top row: passive engagement setting without any direct interaction by the promoter and remaining in one spot. On the bottom row: during the active engagement setting the promoter is able to directly interact and move slightly towards shoppers. In both models engaged shoppers move to the table and take a sample, non-engaged shoppers continue past. The promoter is represented as the square body and shoppers as round bodies. The promoter is trying to achieve the goal of distributing samples. This is a social task first requiring engaging passing shoppers. Therefore, the promoter gestures out into public space for initiating engagement. However, just attracting shoppers' attention is not sufficient to fulfil the goal of the task. It is necessary to motivate shoppers to action, *i.e.* motivating them to take a chocolate sample. Thus, the promoter directs shoppers' attention to the table containing the samples. Finally, the engagement is terminated by gesturing and facing away from the shopper. Whereas the passive promoter cannot move, deliberately gaze towards the shoppers or socially interact with them, the active promoter is free to move and to interact with shoppers. A protocol was created for both the robot operator and the human promoter to follow and this, along with the hypotheses, is described in the following section.

4.2 Methodology

Given the objective, to compare the performance of a robot and a human in promoting food samples, and to analyse the effects of the model of engagement used to achieve this goal, proposed are the following hypotheses:

H1 The robot promoter can engage and motivate people to take a sample with comparable or better performance than a human promoter.

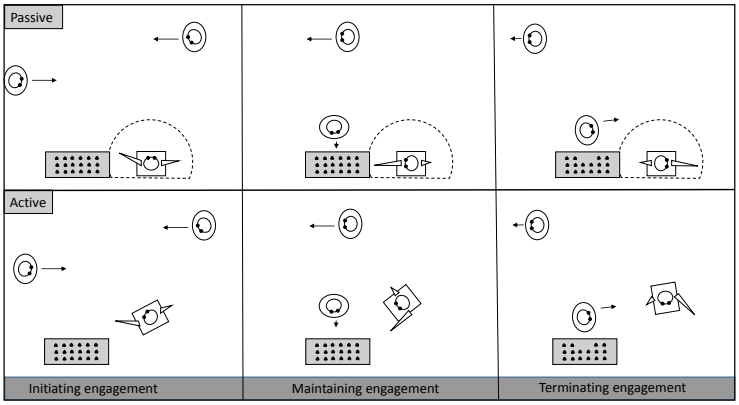


Figure 4.1: The engagement model, as discussed in this work.

H2 An active engagement model significantly increases the number of samples taken compared to a passive engagement model.

To test the hypotheses, the experiment design consists of two binary variables: the promoter promoting the chocolate samples (robot or human) and the type of engagement used (passive engagement or active engagement). This design led to four experimental settings: a passively engaging robot promoter, an actively engaging robot promoter, a passively engaging human promoter, and an actively engaging human promoter.

4.2.0.1 Promoters

The robot used as a promoter was a PAL REEM humanoid service robot[1]. The robot is wheel-based and equipped with a pair of stereo cameras on its head as eyes, with laser and ultrasound scanners for navigation. The robot also has a pair of 4-degrees of freedom (DOF) arms and 7-DOF hands that can perform human-like gestures (Figure 7.2).

The human promoter used during the other settings of this study was a female English native-speaker, aged in her thirties, with sales experience including front of store promotions.

4.2.0.2 Engagement Protocols

Protocols were designed for the active and passive engagement settings. During the passive engagement setting, the protocol required the promoter (both robot and human) to adhere to a specific set of gestures and speeches. The speech employed was randomly

[1]http://pal-robotics.com/wp-content/uploads/2016/03/REEM-Datasheet.pdf

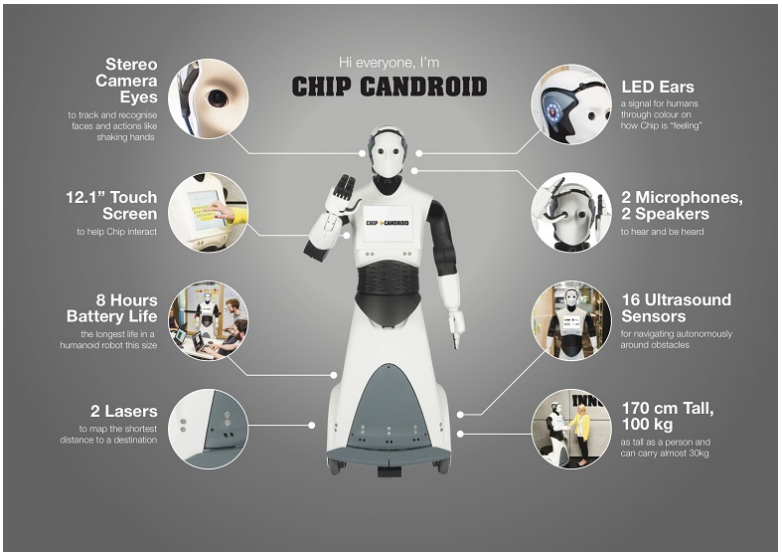


Figure 4.2: The robotic platform used in the study.

selected from a pre-defined list of possible options. The actions of the passive promoter were executed in a specific order as per the following three steps:

1. **Initiation of Engagement.** In this step, the promoter attracts the attention of customers. The robot head turned from side to side, appearing to look out over the study area, scanning the environment. One arm was raised and waved. The randomly selected speech included welcoming sentences such as “Welcome shoppers! This is your lucky day!”;

2. **Maintaining Engagement.** In this step, the promoter promotes the chocolates. The arm was lowered and pointed towards chocolates, the robot head was turned downwards gazing towards the chocolates, to bring user attention to the chocolates. The speech included invitations to taking a free chocolate (e.g. “Life is better with a chocolate, please have one!”);

3. **Termination of Engagement.** In this step, the promoter ends the interaction. The robot head and torso were turned to facilitate the arm to gesture towards a nearby survey/exit area. The speech included thanks and concluding sentences (e.g. “Thank you! Please, take a survey as you leave”).

Between each step, the robot was programmed to wait approximately 10 seconds. Notably, during the passive engagement setting the promoter did not move from its/her location and its/her behaviour was not synchronised with customers approaching or leaving

the study area. The human promoter was asked to refrain from explicitly making eye contact with the shoppers crossing the experiment area and asked her to not directly interact with shoppers, for example, if a shopper asked for directions. When this scenario occurred, a researcher was instructed to appear and interact with the customer instead. At the same time, the human promoter continued to act passively as per the designed protocol, avoiding confusion for shoppers. This protocol was necessary to avoid upsetting shoppers, as agreed with the commercial partner. The researcher interacting with the customer was instructed to not promote, or offer in any way, the chocolates and to limit the interaction as much as possible.

On the contrary, during the active engagement setting, the promoter was free to interact with the approaching shoppers directly, although still adhering to the three steps previously described (initiation, maintenance and termination). Specifically, the robot was teleoperated to simulate an intelligent social agent able to interact with shoppers. Its base was rotated and moved so to direct its face to the approaching shoppers and to briefly move towards them. The robot was programmed to attract shoppers by using the welcoming sentences and by communicating to the shoppers to interact by gesturing with its arm. Therefore, given the experiment was taking place in the wild and the ability of the robot to interact with people, one of the most common occurrences was for people to ask for a selfie with the robot. This is not surprising, since this was one of the tasks the robot was put forward for by the shopping centre management. When it occurred, the robot answered positively and posed for a selfie with the shoppers.

4.2.0.3 Location and Time of the Study

The study was conducted in a two-level shopping centre containing over 150 retail stores, with a strong community of regular shoppers. The robot was introduced in this shopping centre a few days before the study during a public event. The event was recorded and presented on television during a major Australian news broadcast. Thus, shoppers should have had the opportunity to see or hear about the robot, although they were not exposed to the task considered in this study, namely providing samples to shoppers. The setting consisted of a bounded area that was signposted with notification of the study occurring. During the passive engagement setting a rope barricade was used around the promoter. This barricade was removed in the active engagement setting.

Due to technical constraints and agreements with the commercial partner (space available for the study, availability of the robot at the shopping centre and supported length of the study), the study was conducted on the second floor of the shopping centre

during two separate weekdays. For each day, two experimental settings were set up in two separate time slots of 1.5 hours each:

1. **Day one.** Robot promoter settings: passively engaging setting from 9.45am to 11.15am, actively engaging setting from 12.45pm to 2.15pm;

2. **Day two.** Human promoter settings: passively engaging setting from 9.45am to 11.15am, actively engaging setting from 12.45pm to 2.15pm;

The selected days and time slots did not affect the number of potential shoppers available for the study. Previous and post-study statistics showed a comparable number of customers during the selected times and days. However, the choice affected the type of shoppers visiting the shopping centre. In fact, during the morning/early afternoon of weekdays the most frequent customers of the shopping centre are mothers with small children and older adults. However, this was not a limitation for the study but rather a benefit; in fact, the selected times resemble the ones that are usually available for promoting food in the shopping mall, thus providing a good opportunity to test the effects of a robotic platform under circumstances similar to real commercial situations.

4.2.0.4 Measurements

The main objective of this study is to compare the performance of a robot and a human promoter in promoting food samples in a shopping centre, and to analyse the effects of the type of engagement used to achieve this goal.

Free sample promotions can increase store sales on the day of the promotion [169]. Hence a promoter able to give away as many samples as possible, to different customers, is of benefit. Therefore, the number of distinct customers the promoter was able to engage was counted via the number of samples taken. Accordingly, if the shopper took more than one chocolate (for example to distribute them to other customers that did not approach the promoter) counted only was the first pick-up and people approaching the promoter but not taking any sample were not counted (as illustrated in 4.1).

To complement the considered measure, the time was recorded in which the customers took each sample, and therefore the delays between each measurement. This helped to estimate the average speed by which the promoter was able to fulfil the assigned task.

The measurements were taken by an instructed researcher able to observe the experimental area and note the samples distributed in a smartphone application. The customers were not aware of the samples taken being counted.

Table 4.1: Number of giveaway samples during the investigated settings.

	Human	**Robot**	**Outcome**
Passive	30 samples	46 samples	+53%
Active	50 samples	31 samples	−38%
Outcome	+66%	−32%	

4.3 Results

Table 4.1 provides the number of samples given away to distinct shoppers during the considered settings. In agreement with predictions, during the passive engagement condition, the robot performed better than the human by increasing the number of giveaways by 53%. However, contrary to what was predicted, the robot was not able to perform better than the human promoter during the active engagement condition. In this setting, the robot decreased the number of giveaways by 38%. Surprisingly, a robot promoter actively engaging people resulted in a negative trend compared to a passive robot promoter, with 32% fewer giveaways. On the contrary, the actively engaging human performed better compared to the passive human engagement setting by resulting in a positive trend of 66%, as expected.

Besides comparing the overall number of people taking a sample, the speed of execution of the considered task was analysed throughout the duration of each setting. The total duration of each setting (5400 seconds) was divided into time slots of 200 seconds, thus obtaining 27 'checkpoints'. For each checkpoint, the number of measurements was computed (*i.e.* the number of distinct users that took a sample) up to that time. This process led to 27 new measurements for each of the 4 settings. By denoting the sampled measurements with $Y_{sampled}$ and the time checkpoints with X, it is possible to explain the data via the following linear model:

$$Y_{sampled} \approx b + mX \tag{4.1}$$

where b is the y-axis intercept of the line (initial velocity) and m is the gradient of the line (speed). In this analysis, of interest is the average speed to execute the required task. Therefore, to more easily compare the speed between the considered 4 settings the initial velocity factor b was subtracted from the gathered samples, thus obtaining the following normalised linear model:

$$\bar{Y}_{sampled} \approx mX \tag{4.2}$$

where $\bar{Y}_{sampled} = Y_{sampled} - b$. The parameters b and m were estimated for each setting by using the Theil-Sen estimator [145], which is a linear regression algorithm robust

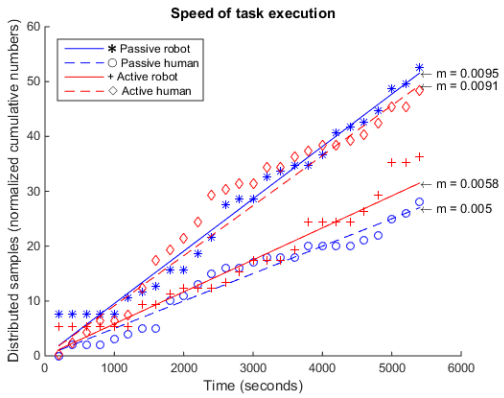


Figure 4.3: Result of the linear regression process over the sampled measurements.

to outliers. Figure 4.3 illustrates the results of the linear regression plotted as per the linear model in (4.2), presented here to visually demonstrate the speed of interactions differs between the two engagement models. The passive robot shows a higher average speed, followed by the active human with comparable performance. On the contrary, the active robot and the passive human show dramatically worse performance, with the passive human resulting marginally slower than the active robot.

A two-way ANOVA was run on the gathered samples $\bar{Y}_{sampled}$ with a confidence level of 95% to examine the effect of type of engagement and promoter on the number of samples given away over time. There was a significant interaction between the effects of type of engagement and promoter, F(1, 104) = 22.46, p = .0000. No main effects were observed between passive and active engagement (p = .5148) and robot or human promoter (p = .5371). The effect size of the observed interaction was measured via partial eta squared [71] suggesting a large effect size (η_p^2 = .1776) [135].

In order to further analyse the observed interaction effect, a one-way ANOVA on the gathered samples $\bar{Y}_{sampled}$ was run to examine the effects between the 4 considered settings. This process led to identifying a significant effect between the 4 settings, F(3, 104) = 7.76, p = .0001 with large effect size (η^2 = .1828) [135]. A Tukey-Kramer multiple comparison was run as a post-hoc analysis to assess the significant effects between the 4 settings. Similarly to that suggested by Figure 4.3, the passive robot resulted significantly faster than the passive human (p = .0014) and than the active robot (p = .0240), whereas the active human resulted significantly faster than the passive human (p = .0013) and than the active robot (p = .0224). No effects were detected between the passive robot and the active human (p = 1) and between the passive human and the active robot (p = .8048).

In summary, it was observed that:

1. The passively engaging robot performed in a comparable way or better than the human promoter for both passive and active engagement conditions. This suggests that a passive robot can engage customers and promote food samples in a comparable way to a human promoter, thus validating the first hypothesis;

2. As expected, the actively engaging human performed significantly better than the passive human. However, surprisingly the actively engaging robot performed significantly worse than the passive robot and with comparable performance with respect to the passive human. These results suggest that the active engagement was beneficial only for the human promoter and detrimental for the robot promoter, thus only partially validating the second hypothesis.

4.4 Reflections

The results of the study present exciting and unexpected results. A potential explanation for the second unexpected result, the actively engaging robot performing worse than a passive robot is proposed below.

4.4.0.1 Further Analysis

The speed to execute the desired task is directly related to the time delays between each giveaway. In other words, the longer the delays between each giveaway, the slower is the observed average speed.

Therefore, to deepen the analyses proposed in the previous section, the descriptive statistics of the measured time delays between giveaways during the 4 considered settings were analysed. The descriptive statistics are summarised in Table 4.2.

The computed means are consistent with the previously discussed results. In fact, the passive robot and active human have comparable average time delays, which are significantly lower than the passive human and active robot conditions showing comparable worse performance. However, although the active robot and passive human present comparable means, their medians are profoundly different. More surprisingly, the computed median for the active robot results in the lowest statistic compared to the other settings and it is less than a half of the second-best median (70 seconds during the active human condition). In addition, the standard deviation for the active robot condition is dramatically higher than the other settings.

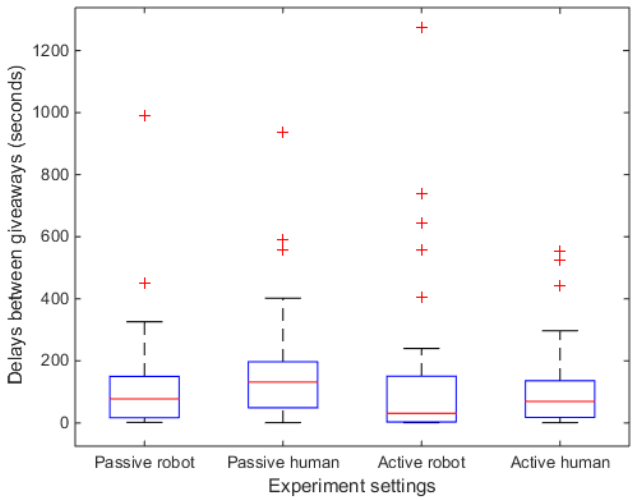


Figure 4.4: The distribution of the time delays collected during the 4 investigated settings.

Table 4.2: Descriptive statistics of the collected time delays.

Setting	Mean	Median	Std
Passive robot	119 sec	78 sec	166 sec
Passive human	180 sec	132 sec	207 sec
Active robot	178 sec	31 sec	293 sec
Active human	106 sec	70 sec	127 sec

This first analysis suggests that, whereas the passive human did, in general, a relatively poor job in distributing samples to the shoppers since both mean and median resulted worse than the ones in the other settings, the active robot was governed by periods of short delays able to reduce the median alternated by long periods of time able to bias the overall mean. Why did this happen?

Based on observations in the field, the suggestion is that the active robot was able to attract groups of people rather than single shoppers and to maintain the customers' engagement for a more extended period of time. When this happened, it created a situation in which many shoppers took the chocolates with short time delays. After the group of people left the experimental area, the active robot took a while before being able to engage another group of people.

To confirm this analysis, measurements were estimated from the number of shoppers taking a sample at the same time. Given a time window of ± 7 seconds, it was estimated the number of shoppers taking a chocolate at approximately the same time by counting how many measurements occurred during overlapping time windows. The results are

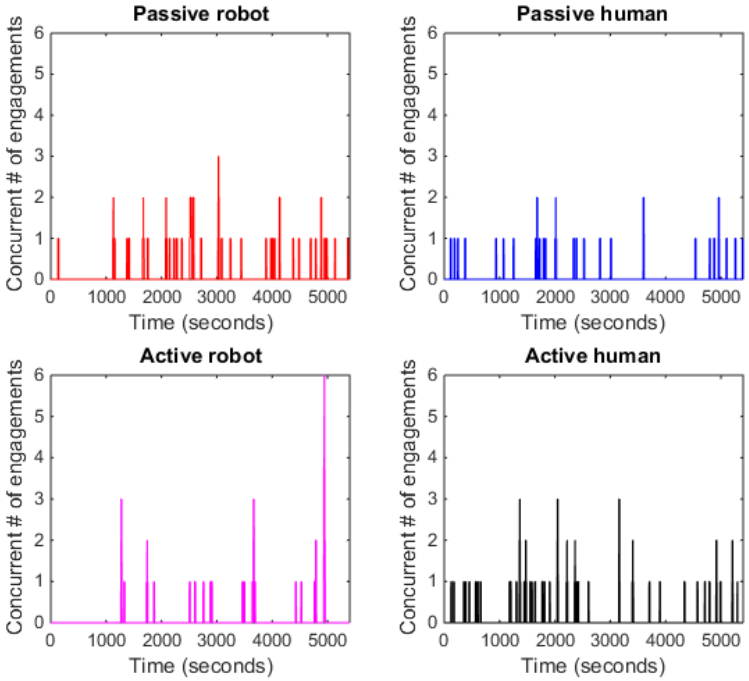


Figure 4.5: Estimated number of shoppers taking a chocolate at similar times (±7 seconds).

illustrated in Figure 4.5 and Figure 4.6.

From Figure 4.5 it is clear to see that the active robot, contrary to the other conditions, is governed by more extended periods of time with no customers taking samples. Furthermore, the active robot presents higher peaks of shoppers taking samples at approximately the same time compared to the other settings. From Figure 4.6 it is possible to compare the frequencies of estimated numbers of shoppers taking samples at the same time. Clearly, the active robot can attract and distribute samples to larger groups of people compared to the other conditions. However, the active human too was able to attract more frequently a larger group of people compared to the passive conditions.

This phenomenon may be explained by the *risk* potentially perceived by shoppers in engaging with the promoter and taking the sample. In the scenario, when customers pass through the experimental area, they can make a decision: engage with the promoter and therefore take a sample or ignore the promoter and leave the area. Deciding on engaging with the promoter underlies many potential risks, such as wasting time, getting embarrassed due to other shoppers observing the situation or feeling obliged to buy the product after trying it. Whenever a decision is taken under uncertain circumstances, as

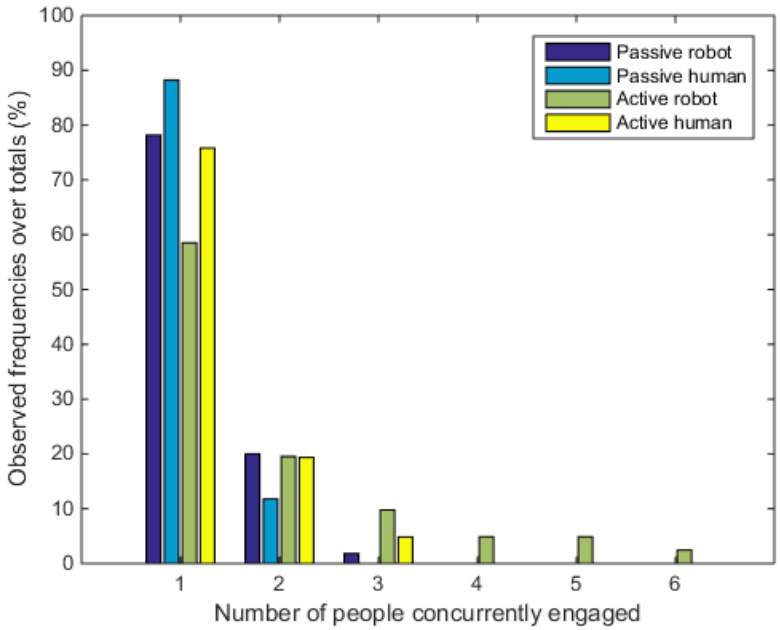


Figure 4.6: Frequencies of shoppers taking chocolates at close times (±7 seconds) during each setting.

in this study, people need to assess the situation and decide whether to take the related risk or not [361]. In a situation such as this, the social surroundings play an important role in the decision making of the individual [308]. Two effects are proposed to be at play. The first effect, it is suggested, may be that known as “social proof” [308]. People consider the behaviour of others to determine their own behaviour, assuming that what others do is the “right” behaviour. This assists with people stopping and joining the group surrounding the promoter. Secondly, psychology studies suggest that the perception of risk can be reduced when taking a decision in a group compared to taking the same decision alone [140]. This effect is known by the name “group shift” or “risky shift” [347].

On initial review, this may be an interesting angle for commercial applications with social robots—would social robots have the ability to create and foster "social proof"? If so, it may be of significant value for a business. However, on reflection, this type of application appears reminiscent of a dark pattern [152, 222], *i.e.* tricking the user into taking an action they might not have chosen freely. Hence, while it may be an exciting effect to study, it is not a direction to be followed for this research project, with its stated values of socially responsible design.

Since during the active engagement conditions, the interactions last longer compared

to the passive engagement conditions, there are more chances for customers to observe a group of people engaging with the promoter. Therefore, given the previous discussion, observing a group of people engaging with the promoter in the experimental area can likely influence the perception of risk of other shoppers passing through the study area and consequently increase the chance of engaging them.

This analysis can explain why during the active engagement conditions, it was observed that more people were taking samples at the same time, which in itself may be considered a form of social engagement. However, it does not explain why the active robot shows more extended periods of times between each engagement. To explain this second phenomenon recall that the considered measurements included only the customers that approached the promoter *AND* took a sample.

During the active robot condition, it was observed that many shoppers approached the robot to interact with it and take selfies. However, they did not take the chocolate sample, thus not being counted in the measurements. In other words, the active robot was able to attract people similar to the active human (Step 1, initiation). However, it was not able to correctly manage the dyadic situations for distributing the chocolate samples (Step 2, engagement maintenance). This was probably because the simulated intelligent capabilities of the robot distracted people from the real purpose of the robotic application, which was not to entertain users but to promote food samples.

As such, an actively engaging and socially intelligent robot able to attract larger groups of people led to a surprisingly detrimental performance when distributing samples. This is an important insight since in this specific activity (and in many other commercial applications requiring customer engagement) it is not important to just attract people, as normally suggested in previous works investigating engagement, but rather to attract people in order to achieve a desired goal, which in this study was to distribute as many samples as possible to distinct individuals. Hence a method for improving the effectiveness of the task would be advisable.

What is clear from the behaviour of people who stop and interact with the robot is that the perceived risk of interacting with the robot changes when other people are present. The actively engaging robot may have presented as a potential higher risk to participants, hence the observed “safety in numbers” phenomenon. This effect is one which may limit the application of the robot in the wild to realise full potential. People increase their risk tolerance for interaction when they observe how other people interact with the robot, hence a method for communicating this to people prior to meeting the robot may assist in accelerating the time it takes for the risk tolerance to be lowered. Suggested methods for

doing this are via media communications, media releases and promotions, that enable people to understand the capabilities of the robot and the behaviour expectations in the considered situation. Additional considerations could include posters surrounding the robot, displaying people interacting with the robot and the expected task interactions. This may be presented via video displays, photos or drawings of people and the robot together. Setting expectations in robot interactions have been explored previously in HRI [220], and this must be considered as a necessary step in social robot deployments until robots are an everyday experience.

In relation to the goal of understanding the experience interacting with social robots and potential applications, it was discovered that a robot is comparable to a human with the specific task of engaging shoppers and giving away samples. The passively interacting robot consistently attracts individual shoppers and engaged with them to give away samples. In contrast, the actively interacting robot gave away fewer samples in total but may draw a bigger crowd when it manages to do so. Further research is required to identify the factors behind this and possible solutions for future commercial applications.

There are some caveats to this finding. Only one type of sample was tested—chocolates—and this may have affected the number and type of shoppers willing to interact. In future studies, different types of samples or products could be tested. Additionally, a different type of humanoid robot could be tested; or comparison between individual promoters and human/robot promoters collaborating, performed.

In addition, the engagement model used is specific to the task; hence the definition of engagement may not apply to different applications not requiring physical user action. Furthermore, due to the engagement model following a set pattern (initiate, maintain, terminate), it did not take advantage of shoppers asking for a selfie with the robot, such as informing shoppers that they must take a chocolate sample before agreeing to pose for a selfie, an insight for future studies. In this area, a human collaborator with the robot would have been ideal, to direct and manage the groups that were forming. Moreover, the study covered a limited time-frame; more extended studies may discover a different or changing effect over time, as shoppers become accustomed to social robots in shopping malls, with the initial novelty of the robot reducing.

Nonetheless, as a first step in formalising the problem space of placing a viable social robot application in the wild, valuable design lessons and an understanding has been gained. The study involved media coverage, a local TV news broadcast, web articles and print media. The value and effect of these media release undertakings should not

be underestimated. Outside of the study, the robot was filmed showcasing its skills in traversing the shopping centre and its potential for future applications. People watched the news broadcast and came to the shopping centre expecting to see the robot in action. This assisted in guiding peoples' expectations when the study was subsequently undertaken, after the showcasing. However, to what extent it set peoples' expectations is unable to be precisely known.

Also unknown is whether the media coverage increased or decreased the novelty effect of the robot in the shopping centre. Novelty is a component of engagement [291] and the media coverage may have increased the interest to interact with the robot. This increase may be suggested by the number of people coming just to take a selfie with the robot. It should be noted however, that groups and people taking selfies with the robot didn't always fulfill the task of taking a chocolate, and hence were not always included in the measuring of the engagement. Therefore, a possible novelty effect was not directly measured, yet presumably present. Future work would benefit from measuring and understanding the impact of media coverage on engagement regarding novelty, and how to design applications to then capitalise on the novelty effect.

Novelty may be thought of as *"an original feature of experience"* [362, p. 412] that highlights the need of sense making and lack of prior knowledge. While studies in HRI suggest attempting to negate the novelty effect with longitudinal studies, Smedegaard suggests we instead think of novelty effects as *"valuable sources of information central to what we seek to investigate"* regarding social human robot interaction [362]. Understanding novelty as indicative of sense making means that we can assess the frame of reference, possible mental models and perceptions, that users may have regarding the interaction with the robot. This allows us then to design applications with specific novelty in mind. However, applications only capitalising on the novelty of a robot may be limited in value if they are also without a genuine task to be fulfilled by the robot.

4.5 Learnings

In summary, this contribution aided understanding towards the research goal in the following ways:

1. *Conducting studies in the wild*
   Further knowledge was gained of challenges to be encountered and of environmental considerations required for future in the wild studies. Before this study, the importance of the robot's placement in a location was not fully understood, nor

the time and extent of effort required by an organisation for media releases. Were this study to be run a second time, factors such as pedestrian flow; architectural impediments; WiFi strength and availability; the number and types of surrounding businesses; length of travel for the robot between overnight storage and daytime use; power supply and availability of power access; would all be considered before placing the robot. Vitally, extra time would be factored in for media demonstrations and communications, separate to study-related tasks. The importance of media releases and promotions to set expectations of people coming to visit the considered environment cannot be overstated. All of the above are factors to consider in any robot implementation and are outside of the usual conditions experienced in the laboratory.

2. *Behaviours*
   Both the behaviour of the robot and the behaviour of people in the proximity of the robot may be factors in people's decisions to interact with the robot, requiring further exploration.

   Firstly, when people stopped to interact with the robot, a crowd would quickly form. What the people's behaviour suggested is that the "social proof" effect is at play [308], *i.e.* they feel less risk from following the choices of others rather than having to think about the situation for themselves.

   Secondly, Höflich describes the following *"the meaning of the robot is not negotiated with the robot as social entity, but together with others in a process of continuous reciprocal indication."* [178, p. 43] and this may indeed be the case for the behaviours encountered during the experiment. The robot itself is not yet socially intelligent enough to manage dyadic interactions and be considered a social entity. However, people behaved as if the robot was a social entity, and this encouraged other people to do the same. People took selfies of the robot and posted them online, influencing others outside the immediate, physical space of the robot. Therefore the "meaning of the robot" can be seen to be negotiated not just in the immediate, physical environment but across the social and digital worlds as well. Hence framing media releases for release online with expected interactions and behaviours *i.e.* video or images of people happily interacting with the robot in the desired task or application may be a way forward for successful implementations.

   Finally, people who went out of their way to avoid walking near the robot and avoided looking in the robot's direction may feel negatively about the robot's

presence in the shopping centre. This may be because of a fear of surveillance or a reluctance to be near a "spectacle". Therefore, ensuring the that robot's behaviours and placement do not require deliberate avoidance of the robot and interaction (*i.e.* no action is required by people who do not wish to interact with the robot), may assist in limiting the possible negative aspect of the robot in the public space.

3. *Application considerations*
   To enable a viable commercial application, a possible way forward could involve collaboration between a robot and human, with the robot promoter in the job of attracting shoppers and the human promoter working to maintain engagement and increase the number of giveaways. Additionally, the robot application could be designed in such a way as to take advantage of the interest people have in social robots, such as only posing for selfies if it is able to fulfill its goal of giving away a food sample.

   The task of giving away food samples was designed as a complete copy of a human-human interaction task. This could be thought of as an effective application design however the design neglected to take advantage of any of the additional, digital capabilities that could be provided by a robot, such as providing communications or interactivity with other media. For example, as people were taking selfies, the robot could have offered to post the photo to the shopping centre website. People could send the photo directly to the robot, from which the robot could then display the photos on its tablet, increasing the interactivity and engagement possibilities with the user. Other possibilities include the robot offering text promotions sent directly to people's mobile phones or allowing users to send feedback to the store or owner directly. Furthermore, the robot could update the store owner's inventory management system of the number of samples taken in real time, allowing an estimation to be made of possible in-store sales to be expected. In-store sales are known to be affected on the day of promotion [169]. This may provide more significant benefit to the robot owner/store owner than possible with a human promoter, due to the real time digital nature of the information.

4.5.1 Open questions

This study has lent itself to the idea that a social robot application may benefit from being more than just a repeat of human-human interactions and task capabilities. It demonstrates that a social robot acting as a samples promoter can have comparable

effectiveness in the application task to a human. However, given the costs and effort involved in deploying robots in public spaces, it would be irresponsible to neglect other areas where the robot application could provide additional value, beyond that of human capabilities. As such the take away from this study is that a social robot application must be designed in such a way that it allows the technological capability of the robot to be exploited, ensuring the full benefit and value comes from the robot's deployment. This idea has been presented before, as Miller and Feil-Seifer state, when describing work by Suchman [369]:

"Rather than taking a design perspective of imitating human-to-human interactions with literal substitutions carried out by the robot, robotics design should engage in engineering alternatives to how humans accomplish particular goals" [268, p. 8]

Before moving on to the next contribution, I investigate this idea in greater depth. If it is suggested that for the full benefit of a social robot to be realised involves incorporating the technological capabilities that are beyond that of a human, are there other (perhaps more cost effective) technologies that instead could be used or that have similar mechanisms of effect? Would using a social robot be just the same as other existing technologies? Can the benefit of social robot technologies be increased by utilising the non-human capabilities of the robot? What does this then mean for the areas of interest still to be studied—privacy and UX?

Communication and capabilities differences in existing technologies are easily identified. These differences are summarised in table form for easy digestion in Figure 4.7. Technologies most similar in functionality to social robot technology are the focus here, and generalisation occurs across standard capabilities.

From the table, it is possible to see those humanoid social robots with tablets (for example, REEM or Pepper robots) cover the largest number of capabilities. As this research is specifically interested in social robots in public spaces, it also includes technologies for shared use, *i.e.* technology that allows access and supports use by multiple parties in the public space. The most similar technology for shared use in public spaces is that of kiosks. Hence in the next contribution, kiosks are investigated as the most comparable technology to a social robot in present use.

As can be seen from the table, the main difference between the robot and kiosk are the communication features—gesture and gaze, and the autonomous movement capability. It is the features made possible by the physical morphology of the robot. One way of looking at these differences is to understand the difference in terms of embodiment. A humanoid robot could be considered as being "embodied" due to the ability to physically interact

shared use technology * may exist in some cases	Communication Ability				Capabilities				
	Voice	Text (inc. images)	Gesturing	Gaze	Camera	Microphone	Internet	Environment Sensors	Autonomous Movement
Computer	✗	✓	✗	✗	✓	✓	✓	✗	✗
Virtual Assistant e.g. chatbot or avatar*	✗*	✓	✗*	✗*	✗*	✗*	✓	✗*	✗
Mobile Device	✓	✓	✗	✗	✓	✓	✓	✓	✗
Voice Assistant e.g Siri, Google Home, Alexa*	✓	✗*	✗	✗	✗*	✓	✓	✗*	✗
Kiosk	✗*	✓	✗	✗	✓	✗*	✓	✗*	✗
Social Robot e.g. Knightscope	✓	✗	✗	✗	✓	✓	✓	✓	✓
Humanoid Social Robot	✓	✗	✓	✓	✓	✓	✓	✓	✓
Humanoid Social Robot with Tablet	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 4.7: Differences in technologies

with the surrounding environment, through sensors and motors [429]. Embodiment has been highlighted as being of particular importance in HRI [21], especially in regards to comparing virtual agents and physically embodied robots. For example, it has been shown that an embodied robot is considered more appealing and enjoyable compared to a non-embodied agent [401]. Hence, the embodiment of humanoid social robots, differentiating them from other technology, is explored in the next contribution.

4.6 Next contribution

The next contribution builds on the learnings from this study. A task that a human cannot perform without technology use is investigated, in order to take full advantage of the digital capabilities of the robot. A kiosk (disembodied) is compared to a humanoid robot (embodied) in performing a task that requires social interaction and potential risk for the participant, giving rise to privacy considerations. Hence, both privacy and embodiment are explored. Furthermore, we design for transparency, as it is considered a method of importance in Privacy-by-Design approaches. Hence we are able to explore how designing for privacy, via transparency, impacts on the User Experience (UX) of the interaction with embodied and disembodied technology.

CHAPTER 5

DESIGNING FOR PRIVACY WITH SOCIAL ROBOTS

"The harms at issue are hard to identify, measure, and resist. They are in many instances invited. And neither law nor technology has obvious tools to combat them. Our basic recourse as creators and consumers of social robots is to proceed very carefully." Ryan Calo [55, p. 198]

Chapter Summary *Experiment B: Privacy and its effect on UX in HRI. Location: CBA Innovation Lab. My Role: Researcher, Interaction Designer.*

Purpose *Discover the effect of designing for privacy on the user experience with social robots. Determine if there is a difference between social robots (embodied) and comparable, disembodied technology when providing transparent and non-transparent communication.*

Methodology *The robot is compared to a kiosk in the task of face enrolment and Facebook connection, with either transparent or non-transparent communication regarding the processing of data.*

Findings *The embodied robot is comparable to the kiosk in people agreeing to face enrolment. The robot received more consents to connecting on Facebook than the kiosk did however, this was only significantly different when in the transparent condition. The transparent system led to a more positive user experience.*

Contributors *This chapter incorporates the work and findings produced in collaboration with Jonathan Vitale, Suman Ojha, Jesse Clark, Sammy Pfeiffer, William Judge, Xun Wang, Mary-Anne Williams, and Sarita Herse; variously published in Kheddar A. et al. (eds) Social Robotics. ICSR 2017. Lecture Notes in Computer Science, vol 10652 [383], in the Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction [396] and in The 2017 AAAI Spring Symposium Series: Technical Reports [397]*

The previous chapter explored the idea that a social robot is a unique technology in its ability to mimic human roles. However, it was argued that social robot applications would benefit from providing more functionality than that of a replicated human task. Allowing the robots' full value to be realised by an experience enhanced from both the digital and physical worlds is instead the ideal. Social robots can seamlessly connect to the digital world and data collected from these interactions can be stored, processed or used to provide additional benefits, beyond that possible from a human. However, using data in this way for a real world application by an organisation, additionally requires as a bare minimum, meeting current privacy legislation. This chapter, therefore, investigates an issue of essential importance in this project, namely privacy, and its effect on the user experience.

Legislation guidelines recommend following a Privacy-by-Design (PbD) approach for consumer privacy. Privacy and social robotics is currently an area only recently gaining interest in the robotics and HRI field. Additionally, precious little is known regarding how the privacy-sensitive design of an interaction will affect the user experience, as evidenced by studies on UX and the limited studies concerning privacy (see Sections 2.4 and 2.7.1). Therefore, to further develop an understanding of the problem space for social robot applications, I explore this issue. Using a Privacy-by-Design approach in the application design for two shared-use devices is compared: a social robot and a kiosk. The social robot is considered as an 'embodied' technology. Using identical data collection situations, we test to see if people provide more personal, private information to an embodied social robot than a kiosk. Additionally, transparency, a core component of privacy design, is investigated to assess if there is a difference reported by users regarding the user experience when it is used.

Therefore, with this study, privacy best practice is brought into the social robot application design, allowing investigation of the effect of designing for privacy in HRI on UX. This allows greater understanding of how to best design socially responsible applications for social robots to be deployed in the real world.

5.1 What happens when using a Privacy-by-Design approach for social robots?

Robots co-existing with humans need to master social intelligence capabilities [398, 416], for example, the ability to establish and maintain a relationship with users [237] or of making ethical decisions [293].

These social skills present with unique privacy challenges [397]. Dautenhahn and Salem [332] describe how a socially intelligent robot requires capturing real-time personal information about a user, enabling it to interact, respond and adapt appropriately to a user's behaviour in an interaction. For instance, if a user tells a robot their name, they may expect the robot to remember their name and recognise their face throughout the present and future interactions, the way a human might do. For a robot to do this, it may involve recording and storing information regarding a user's identity and appearance, for example their gender, age, face and name; a user's previous interactions and behaviour; and people associated with the user (friends). This storing of personal information raises issues regarding privacy; however, without this ability, the robot is effectively socially un-intelligent. Hence a method to allow a robot to function in real-time as a socially intelligent robot while also being cognizant of privacy issues is required.

Furthermore, the robot may need to provide functional capability beyond that of social mastery, requiring to update external databases or share information regarding the user's actions or preferences and requests to other parties. This shared use of personal information collected by the robot requires explicit consent from the user in current legislation.

A Privacy-by-Design approach, which incorporates privacy considerations into the design of the system [397], recommends allowing users a choice and seeking their consent for the use of their personal information, and is commonly recommended in privacy legislation in use today [319]. This practice is already regularly experienced in an online human-computer interaction such as when a user is on a website or mobile app, and is also considered beneficial for business [415]. Indeed it is recently just now appearing in robotic literature as a possible approach for meeting the legal requirements of the EU General Data Protection Regulation [173].

Moreover, a Privacy-by-Design approach focuses on mitigating possible privacy risks by limiting data collection and processing. Additionally, the user is provided with a choice regarding their data and informed regarding the data management (collection, use, storage and sharing). This transparency regarding the management may allow users to assess their perceived risk and to inform their choice in the allowing of the collection of their personal data. Conversely, this action may increase the user's level of trust in the entity that is collecting the information [82].

Despite systems using necessary precautions such as these, the majority of naïve users do not know the underlying details of information processing such as the machine learning algorithm used, what data the system would then store, and how. This lack

of *transparency* can lead to privacy concerns and additionally, to violation of privacy laws [303, 319]. As robots may be autonomous, mobile, and sharing public or private space such as shopping malls or homes with users, their possible impact on users privacy is significant. Complex sensors on the robot allow multiple methods for recording and assessing data, and these cannot always be seen, identified or understood by a user. Nor may it be clear whether information storage and processing are undertaken inside the robot or in the cloud. Hence this investigation seeks to address these issues by providing information to users regarding the data collected and its processing, e.g. the machine learning process employed by the robot to perform its role.

Furthermore, in a social robot-human interaction, a different expectation of privacy may be occurring in users, due to the embodiment of the robot and the social nature of the interaction. Hence it is suggested the Privacy-By-Design approach may not translate as effectively across disciplines. Users may not carefully consider the possible impacts on their privacy when dealing with an embodied social robot, even when informed of the information being collected and used. They may assess privacy risks differently due to the sociality of the experience with the embodied robot and possibly trust the robot more due to its transparency regarding personal information management. In addition, the actual social interaction between human and robot may involve anthropomorphising of the embodied robot by the user, and this may prompt the user to disclose private or sensitive information [234]. This may then reduce the effectiveness of the Privacy-by-Design approach. Hence, this study investigates embodiment and what may occur when privacy considerations arise.

Therefore, this investigation seeks to answer two research questions:

R1: *What is the effect of embodiment on privacy considerations?*

Assessing if there is a difference occurring when an embodied social robot uses PbD compared to a similar, non-embodied technology using PbD. Hence analysis is firstly focused on embodiment by advocating the following hypothesis:

Hypothesis 1 Embodiment (H1): *an embodied system is able to increase users' risk tolerance when providing their private information through the system, thus reducing the user's privacy concerns as compared to a dis-embodied system.*

Secondly, what is the effect of the transparency on the user experience?

R2: *Does transparency affect user experience for social robots?*

It is put forward that it is vital to *understand how disclosing transparent information about data management to users, as per a PbD approach, affects their privacy considerations, potentially biases their decisions, and influences their user experience*. Gathering insights around this topic will advance on the validity of the following hypotheses:

Hypothesis 2 Transparency (H2): *A transparent system increases users' risk tolerance when collecting their private information, thus reducing user's privacy concerns and significantly increasing the quantity of collected private information, as compared to a non-transparent system.*

Hypothesis 3 Transparency (H3): *A transparent system leads to a better understanding of the system by the user and, consequently, to a significantly more positive user experience as compared to a non-transparent system.*

An important original contribution of this work is the unification of privacy research, regarding embodiment and transparency, with User Experience (UX) Design. This approach draws inspiration from Privacy-by-Design [223, 397, 415] and recent work regarding privacy and robots, referred to as a *privacy-sensitive* approach [303, 328]. A privacy-sensitive design approach ensures privacy protections are introduced at the beginning of system design, rather than retrospectively added at the end.

This is particularly important when designing commercial robot applications in real world human-centric business environments [415]. Indeed, existing systems built without including privacy considerations as a core part of their development often result in poor privacy management and a lack of user adoption [415]. The findings of this study can benefit privacy policymakers to provide legislative tools to better protect the privacy of users in the particular context of robots. In addition, they can help businesses deploying social robots to ensure they comply with the law.

Furthermore, the investigation is not limited to the effects of transparency for robotic applications, but extending it by including a comparison with much more widely available technology, namely interactive kiosks. Therefore, this exploratory research provides a different understanding of privacy-related phenomena and suggests how they can potentially translate from current technologies to future robot systems. Thus, this

research benefits the design of future commercial robotic applications that need to adhere to current privacy legislation, while at the same time maintaining positive user experience.

The next section explores related privacy works in two areas in HRI. Firstly investigated is embodiment and the HRI literature regarding privacy. Secondly, transparency and user experience.

5.1.0.1 Embodiment and Privacy in Robotics Research

In psychology literature, the term *'embodied'* usually refers to body parts, bodily activities, or body representations [138]. In social robotics, this feature becomes of supreme importance for establishing proficient human-robot interactions, since it affects user perception towards the robot [161] and it biases human expectation [220].

Since the focus of this investigation is oriented on humanoid robots [176], *embodiment* is defined as a characteristic of having human-like bodily features such as head, arms and hands. In addition, a robot is considered to be embodied only if its physical body can interact with the environment, through sensors and motors [429]. This additional feature of embodiment is necessary to avoid including digital devices contained in dolls or mannequins in the definition, since these tools cannot move or sense the environment. Embodiment is considered an important attribute to enable social tasks between humans and autonomous agents. [400].

Researchers have found that people expect more natural and autonomous interaction from embodied robots than disembodied robots [230]. Moreover, Wainer and colleagues [400] found that an embodied physical robot can maintain a long-lasting interaction as compared to a simulated virtual robot in their experiments. Likewise, Wainer and colleagues also found that physically embodied robots were perceived as more helpful and enjoyable by the participants of their experiment [401]. However, studies examining the *relation between embodiment and privacy consideration* are sparse. The work of Caine and colleagues [54] is distinct in investigating embodiment and privacy in robotic applications. The authors investigated the effects that a stationary camera, a mobile robot and a stationary robot have on users' privacy concerns. Contrary to their expected hypothesis, they found that people in the stationary camera condition exhibited more privacy consideration behaviours compared to the mobile robot condition. These findings suggest that people, in general, feel more comfortable to interact with embodied robots.

Although Caine and colleagues' work [54] investigates a topic similar to this experiment, their robot—contrary to this—has no human shape but only wheels to move and a

simple camera mounted on top of the robot. The robot was remotely teleoperated and incapable of gesturing, speaking, or sensing the environment.

Contemplated as a whole, these studies may indicate that embodiment combined with anthropomorphising (specifically the assigning of human intentions and behaviours to the robot) by the user, may lead to privacy expectations, regarding the appropriate sharing of and expected use of the types of information, similar to that which occurs in a human-human social interaction. This is inline with the expected CASA(Computers as Social Actors) [311] and social presence effect.

Regardless, the literature still does not sufficiently explore how embodiment affects a user's privacy considerations—especially when considering the storage of privacy-sensitive information such as a biometric template for facial recognition. Understanding if there is a difference in the personal information collection consented to by users when interacting with a social robot is a factor in the motivation for this study. It may imply re-consideration of legal safeguards regarding privacy are required, in a future where social robots are pervasive throughout society. By recognising this phenomenon and incorporating this understanding into a Privacy-by-Design approach it is possible to future proof the design of social robots, avoiding potential privacy impact risks and meeting expectations critical to user trust and acceptance.

5.1.1 Transparency, Privacy and User Experience

Currently in Australia, for applicable large organisations, collection of sensitive information requires a user's consent [292]. Also, the user must be informed as to the use, sharing and storage of the information, to ensure the user can make an informed choice with regards to providing their personal information. Collection and management of personal information must be open and transparent, with a clearly expressed privacy policy.

Transparency is defined in relation to the clarity of the information provided by a system to an individual about the collection, processing, storage, usage and sharing of their private information when interacting with the considered system. It is important to note that transparency is commonly required by privacy legislation around the world [303, 319]. Specifically, it is necessary to provide users as much information as possible about the collection of their private information and a pointer to the considered privacy policies, including references to current legislation and users' rights. Thus, investigating the effects of transparency on privacy and user experience is fundamental to gather sufficient guidelines to better design future robotic applications by incorporating privacy

considerations into the design of the system from the very beginning, as recommended by a privacy-sensitive design approach [223, 319, 328, 415].

Effects of information transparency on privacy concerns and trust towards the system have been previously investigated. Wu and colleagues [423] found that the way the online privacy policy is presented to users significantly affects their *privacy concerns* and that this, in turn, influences users' trust. In line with this, other researchers also concluded that disclosing information handling practices of a company helps to reduce privacy concerns [83, 224], which in turn improves the *trust* of the individual towards the system [175] and enhances the *willingness to provide personal information* [101, 423].

Previous research supports the fact that the transparency of a system has an impact on a user's experience in using a system. For example, Sinha and Swearingen [358] found that a recommender system which explains the mechanism involved in the process of making a particular decision is liked more by the users, and users experience a feeling of greater confidence in following a recommendation given by such a system as compared to a less transparent one [358]. Additionally, Konstan and Riedl stress that increased transparency of explanation of the underlying mechanism helps to improve user experience in recommender systems [213]. However, the role of transparency in user experience design has primarily been investigated in settings of recommender systems [213, 358] or non-humanoid robots [421].

One of the few works investigating transparency for robotic technologies is that of Kim and Hinds [210]. In it the authors explored the effect of transparency on the tendency to blame a robot, the self or other participants when something goes wrong during an assigned task. Although this work investigated transparency for a robotic application, it did not investigate the effects transparency has on privacy and user experience.

A very recent study, undertaken after this study was published, involving social robots and transparency was conducted by Felzmann *et al.* [117]. A checklist was provided on implementing transparency in robot development. However, no concrete use cases were provided from which this checklist was created, limiting its usefulness for real world applications. Furthermore, the possible effect on peoples behaviour and the user experience was missing from the literature.

Thus, a significant novel contribution of this study is the provision of a more comprehensive understanding of transparency for human-robot interaction (HRI) applications by investigating effects on both privacy and user experience within a single experimental study. This work aims to further the privacy-sensitive robotics research that focuses

on the deployment of real robots in commercial applications deployed in human-centric business environments [328].

5.2 Methodology

The experiment is situated in the Innovation Lab of Commonwealth Bank of Australia (CBA) where user experience research is undertaken with new technologies before real-world deployment. This lab focuses on studying and developing innovative products and services, in collaboration with customers, partners, government, startups and industry.

One of the primary skills a robot must demonstrate to achieve social intelligence is recognising people. This skill involves memorising human identities so they can be identified again at a later date, therefore facilitating social exchanges [165]. For digital systems, this task involves the recording of user's sensitive information, thereby creating an optimal use case to frame this investigation on privacy.

5.2.0.1 Robot Platform

The robot platform used in this experiment is a REEM robot[1] a human-sized humanoid robot with a wheeled base, equipped with a pair of stereo cameras on its head (for eyes). The robot has a pair of 7-degrees of freedom (DOF) arms and 3-DOF hands that can perform human-like gestures. Built into the front of the robot at chest height is a touch screen, which is used during the experiment to display the Graphic User Interface (GUI) of the face enrolment system under investigation. During the study, the robot communicated with the user through gestures, speech, and text on its monitor.

5.2.0.2 Experimental Design

This study considers two independent binary variables: *embodiment* (*i.e.* either embodied or disembodied) and *transparency* (*i.e.* either transparent or not transparent), thus leading to a 2×2 between-subjects design.

Embodied and disembodied conditions. During the embodiment conditions, the participants interacted with the humanoid robot through the monitor integrated into its chest. The text of the GUI was simultaneously acted through robot speech and gestures. During the disembodied conditions, the participants interacted with an interactive kiosk,

[1] http://pal-robotics.com/wp-content/uploads/2016/03/REEM-Datasheet.pdf

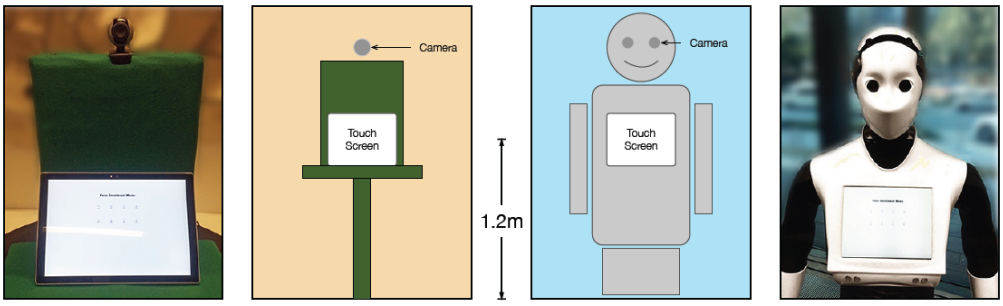


Figure 5.1: Face enrolment setup on the REEM robot and the alternative disembodied setup on a kiosk-like setup.

namely a tablet connected to a webcam. The tablet has the same dimensions as the robot's monitor, and it was situated at the same height. The webcam was placed at the same height as the robot's cameras (Figure 5.1). The GUI used on the tablet was exactly the same as the one used on the robot's monitor, with the only difference being that the text was not acted through speech and gestures.

Transparent and non-transparent conditions.

The transparent conditions differed from the non-transparent conditions by including additional stages in the face enrolment interface, informing the user about the face recognition algorithm used, how the data was recorded and stored, and legal privacy policies followed by the bank to store the private information. In the transparent condition, this information was communicated after the welcoming interface and right before asking the user's consent to proceed.

In this study, the user's facial features were only pretended to be collected by the robot. Thus no users' private information was actually collected throughout the experiment. However, in order to elicit users' privacy considerations, the interface signalled the intention to collect their private information in all the considered experimental conditions from the first screen presented to the user (see section 5.2.3 for a summary of the user interface flow).

5.2.1 Participants

Participants were invited to join the experiment via e-mail sent to 'friends of the lab', namely a mailing list of CBA staff, partners, guests, visitors and the general community of the CBA innovation lab. All participants were proficient in English reading and

listening, and evenly varied in terms of computer literacy.

A total of 84 people expressed the intention to participate in the experiment. However, in a post-experiment questionnaire participants were asked which social networks accounts the participants used. Since in the experimental methodology, Facebook was used to elicit user privacy considerations, 9 participants were discarded for not owning a Facebook account from the study. Also excluded were 3 additional subjects due to technical issues preventing the user consent data recording, thus leaving a total of 72 participants (41 males and 31 females, ranging from 18 to 60 years old).

Each participant was randomly allocated to one of the four experimental conditions as summarised by Table 5.1.

Table 5.1: Number of participants allocated to the 4 different experimental conditions

	Embodied	**Disembodied**	***Total***
Transparent	21 (29%)	20 (28%)	41 (57%)
Non-Transparent	15 (21%)	16 (22%)	31 (43%)
Total	36 (50%)	36 (50%)	72 (100%)

5.2.2 Procedure

The experiment included three main stages: (1) an introduction of the experiment to the participants together with a pre-experiment questionnaire (to collect data like gender and age group), also a quick tour of the labs; (2) the interaction with the face enrolment system in one of the considered four settings; (3) a post-experiment questionnaire evaluating the participants' user experience.

5.2.3 Face Enrolment System User Interface

The user interface of the system started with a **welcome page** providing the following message: "We would like to take your photo so we can welcome you back next time you visit". This screen was common to all the experimental conditions and necessary to signal to the users the intention of collecting their private information.

After the welcome page, if the participant was in the non-transparent condition, the system directly proceeded with the **user consent page**. This screen provided the following message: "Can we remember your face to greet you next time you visit? *[button NO] [button YES]*".

In the alternative case of the transparent condition, before asking for user consent, the system provided information about data processing and storage, and the privacy

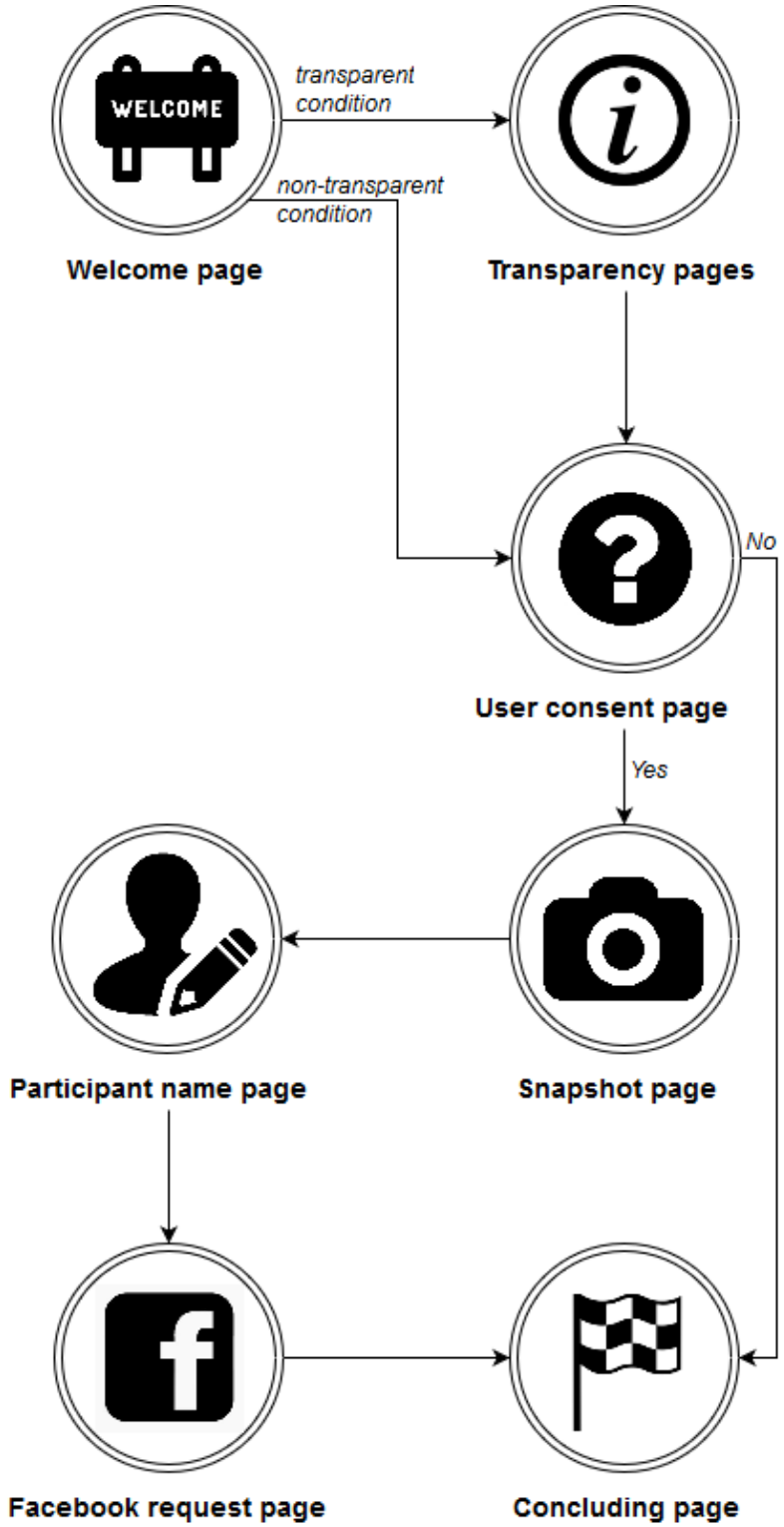


Figure 5.2: The user interface flow of the face enrolment system.

policy through a set of **transparency pages**. The user was provided with the following information: "We can take a photo of your face, and convert your features to the equivalent of a digital pin. Something like this *[it follows an image of a face and a long sequence of corresponding numbers]*. We store these numbers, not your actual photo, and keep them securely in our database. The numbers cannot be used to recreate your photo. Only we can use the numbers to recognise you next time you come to visit. We do not share your information with anyone and will only use it to greet you. Our privacy policy can be viewed at anytime online at *[it follows a url]*."

If the user consented to proceed, the **snapshot page** was presented showing a countdown of 10 seconds together with video camera feedback. The feedback was necessary to show the users that the camera was recording their faces and therefore simulating a real data collection. Nonetheless, it did not actually take pictures of the participants. In the case the user did not provide the consent the concluding page was shown and the experiment terminated.

If the experiment proceeded, the system presented the **participant name page** asking the participant for their name through an input textbox and providing the following message: "Could you tell me your name?".

From previous pilot experiments and surveys [397] it was discovered that asking participants to record their face is not enough to elicit privacy considerations and detect effects on privacy in the considered context (see section 5.2.4 for a discussion). On the contrary, the previous pilot studies showed that asking users to connect to their Facebook accounts was assessed as an inappropriate intrusion of users' privacy in this context. Therefore, included in the interface was an additional **Facebook request page** asking user's consent for connecting to the Facebook account of the participant: "Thank you [participant's name]. It's nice to meet you! Let's stay in touch by connecting on Facebook. Is that okay with you? *[button NO] [button YES]*". This second privacy check was used as a more powerful way to elicit users' privacy concerns, therefore better detecting effects on privacy, as I will discuss later in section 5.2.4.

Finally, the experiment ended when the system displayed the **concluding page** by saying: "Okay! See you next time!". This message was standard for all four experimental conditions and for any answer given by the user (either agree to consent or disagree).

Figure 5.2 provides a summary of the user interface flow for all four conditions of the experiment.

5.2.4 Measures

5.2.4.1 Privacy Measurements

Measuring privacy concern is a difficult task, as actually asking users directly regarding their general privacy concern has been shown to be unreliable [2]. Similarly, users will tend to overstate privacy concern if primed, the "privacy paradox" where users stated intentions to disclose private information is different from a users actual behaviour in disclosing private information [288]. Nevertheless, it is also understood that privacy judgements are very much contextual [286]. Hence the design took the following steps, inspired by the first three principles of Krol *et al.* regarding robust experimental design for security and privacy [216, p. 21]: *"(i) give participants a primary task; (ii) incorporate realistic risk; (iii) avoid priming the participants;"*

(i) **Primary Task**

As Krol [216] describes, giving users a primary, realistically situated task provides them with a focus for attention. In real life, users are interacting with a computer, or in this case, robot, in order to achieve some goal. For example, seeking a recommendation for a restaurant. Privacy is a secondary consideration, separate to the goal's main purpose. Hence by providing users with a primary task with a meaningful purpose in a realistic situation, it ensures external validity and transferability to the real world.

The experiment was situated in one of the primary steps necessary to demonstrate proficiency in social intelligence, namely that of memorising and storing a users face so they can be recognised again at a later date.

The primary task chosen for users was to evaluate the UX of the face enrolment system, an essential study in itself for creating positive user experiences with machine learning systems. Users were requested to interact with the face enrolment system after having a quick tour of the bank's innovation lab[2]. Then, they were asked to provide their evaluation via the User Experience Questionnaire (UEQ) [225] on an iPad. This background story was necessary to divert the focus of the participants from privacy research and avoid priming the participants. This task was additionally chosen as the environment in which the study took place was a

[2]An area of the bank where new digital services are investigated and are exhibited available current or future technologies.

financial institution. Hence, it would not be out of the ordinary to have a system for collecting users facial information (face enrolment).

(ii) **Incorporating Realistic Risk**

When participants know a situation is a simulation, they may behave differently to how they would in real life. Without a threat to the participants' perception of risk, it limits the external validity of the experimental results. "Realistic risk" occurs when participants perceive a threat to the privacy of their personal information [216].

Additionally, participants providing personal credentials has been directly assessed in security studies [340]. It was found that participants using their actual banking credentials had much more security-conscious behaviour to those who were using simulated banking credentials. Hence a method asking users to use their personal information in the study may heighten perceived risk.

Usually, requiring users to record their facial features may elicit privacy concerns. However, financial institutions are usually perceived as reliable organisations by users for safely storing their personal information [388]. In addition, many large organisations, such as banks, already ask their employees to release their biometric information (*e.g.* photo ID, fingerprints, face biometrics, *etc.*). Hence, asking participants to memorise their face together with simple additional private information (*e.g.* name, address, telephone number, *etc.*) may not be perceived as a risk, thus not raising sufficient privacy concerns by users. This is in line with Nissenbaum's contextual theory of privacy [287] where individual privacy expectations are defined according to social norms. By following what information practices are considered acceptable in a given context, it could be expected not to raise privacy concerns. Therefore, in order to raise privacy concerns, the robot also asked to collect information that may be considered outside of regular practice for a banking institute *i.e.* personal information such as connecting to a social network.

To test this hypothesis, a preliminary survey was conducted among 282 people (bank staff, customers, students) [397]. It was discovered was that a robot collecting information such as name, address and phone number was considered to be 'okay' 36.82%, or 'definitely okay' 20.94%, in a bank. In addition, it was expected that by asking the users to provide access to their social networks accounts would be perceived as an intrusion outside the normal boundaries perceived appropriate for a bank institution. Indeed in the same survey, only 8.96% of users expressed to

be 'okay' and 4.48% 'definitely okay' with the robot in a bank asking to connect to social networks.

Therefore, in this experiment, two privacy checks were employed as an indirect measurement of users' privacy concerns.

- The first privacy check counted how many users consented to a photo of their face being taken. It was aligned with what was expected to be found in the working prototype of the designed face enrolment system.
- The second privacy check counted the number of participants who agreed to connect the face enrolment system to their Facebook account.

The second privacy check provides a higher threshold than the first privacy check. It allows us to measure the impact on the UX of a participant's privacy tolerance during the face enrolment experiment. Contrary to the first privacy check, the second check would not be expected in actual deployment of the designed system.

The rationale behind this choice is that, based on the preliminary survey, the first privacy check may not be strong enough to trigger privacy concerns among different experimental conditions. On the contrary, the second privacy measurement may be strong enough to signal the effects of privacy considerations in users. Hence, the second privacy measurement is used to indirectly measure the reduction or enhancement of privacy concerns in the participants between embodied and dis-embodied / transparent and non-transparent conditions. It is suggested that embodied and dis-embodied / transparent and non-transparent conditions would set certain risk tolerance "comfort zones" in the participants.

Therefore, assuming that the two privacy measurements would be perceived by the participants, on average, to have certain levels of risk, it is suggested that during the embodied condition the risk tolerance would be higher compared to the dis-embodied condition. Hence, it is predicted that fewer privacy concerns will be observed in the embodiment settings compared to the dis-embodied ones. Figure 5.3 visually explains this hypothesis.

Similarly, it is reasonable to assume that transparent and non-transparent conditions would also set particular risk tolerance "comfort zones" in the participants. Therefore, assuming that the two privacy requests would be perceived by the participants, on average, to have certain levels of risk, it is suggested that during the transparent condition the risk tolerance would be higher compared to the non-

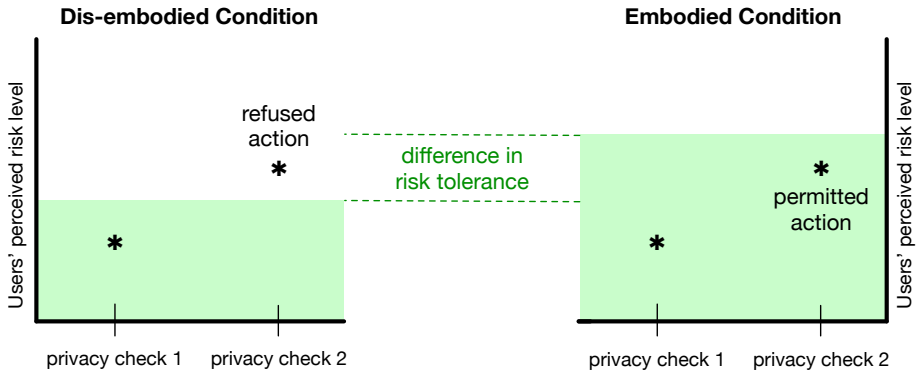


Figure 5.3: Visual explanation of the embodiment hypothesis

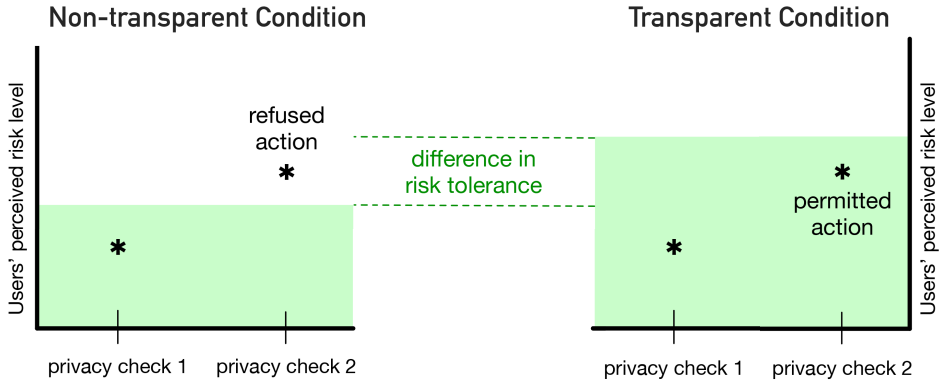


Figure 5.4: Visual explanation of the transparency hypothesis

transparent condition, where the participant would not have any reassurance about how the data would be stored and managed by the organisation. Hence, it is predicted fewer privacy concerns and, consequently, a more positive user experience in the transparent settings as compared to the non-transparent ones. This hypothesis is again visually explained with the same understanding Figure 5.4.

(iii) **Avoid Priming the Participants**

Priming occurs when information is made visible to participants that might influence how they behave in the experiment. This can lead to the participant providing answers that they think the experimenter expects. [216] This can be avoided by providing only generalities concerning the study or omitting descriptive information. Ethical issues that arise from this approach are addressed by debriefing participants at the end of the study as to the full purpose of the experiment. It should be

noted that while this is an accepted approach in psychology studies, it can lead to participants distrusting researchers in future studies.

In the study, the participants were invited to participate in the study via e-mail sent through the mailing list system used by the bank for inviting people to join social and UX events organised by the lab. In the invitation, the study was described as investigating the UX of a new system designed for the lab. Not mentioned was anything about privacy or social networks. At the beginning of the experiment an information sheet was provided to the participants describing the study as investigating the UX of a new human-machine interaction system. Only at the end of the experiment were the participants debriefed about the full nature of the experiment and the privacy-related components of the research.

5.2.4.2 Reaction Times

The participants' reaction time of deciding to agree or disagree with providing access to their private information was measured. This measurement was taken on both user consent pages for both the face recording and Facebook connection request. This was to investigate if there are significant differences in time reactions during these decisions and, consequently, delays due to additional cognitive loads possibly caused by further privacy concerns when deciding whether to share private information.

5.2.4.3 User Experience Measurements

For measuring the user experience of the considered system, the User Experience Questionnaire (UEQ) by Laugwitz, Held and Schrepp [225][3] was used.

This questionnaire consists of 24 pairs of contrasting qualities that participants should judge with regards to the experienced face enrolment system. The qualities are scored by gradations between opposites on seven-steps Likert scales. The seven-step scale was used to reduce the central tendency bias for such items.

The considered qualities are organised into six groups: Attractiveness (*e.g.* good/bad, annoying/enjoyable), Perspicuity (*e.g.* complicated/easy, not understandable/understandable), Efficiency (*e.g.* fast/slow, organised/cluttered), Dependability (*e.g.* unpredictable/predictable, secure/not secure), Novelty (*e.g.* creative/dull, conservative/innovative) and Stimulation (*e.g.* motivating/demotivating, boring/exciting).

[3] Please refer to http://www.ueq-online.org/ for related details and data analysis tools.

The UEQ was administered to the participants via a portable iPad after the interaction with the face enrolment system.

5.3 Results

The significance level was set to an alpha equal to 0.05. For the considered analyses the software Minitab[4] was used.

5.3.1 Analysis of User Consent

The number of participants who agreed to have a photo of their face taken, by the robot or kiosk, was recorded. Among the participants giving their consent to proceed with the face enrolment process, the number of users providing their consent to connect to their Facebook account was also recorded. These measurements returned the proportions of users giving their consent during the first and second privacy check. Table 5.2 summarises the number of participants who provided consent to enrol their face, as well as the number of participants who accepted the Facebook connection request after giving consent to proceed with the face enrolment process.

Table 5.2: Summary of the participants who gave their consent to enrol their face in the system and accepted the Facebook request.

Face enrolment	**Disembodied**	**Embodied**
Non-transparent	16/16 (100%)	14/15 (93.33%)
Transparent	18/20 (90%)	21/21 (100%)
Facebook request	**Disembodied**	**Embodied**
Non-transparent	7/16 (43.75%)	8/14 (57.14%)
Transparent	4/18 (22.22%)	11/21 (52.38%)

In Fig. 5.5 and Fig. 5.6 are illustrated the results of the experiment. From the plots, it is clear to see that although there are no noticeable differences for the first privacy measurement (face enrolment agreement), the embodied system can collect more positive responses from users for the Facebook connection privacy check. This effect is noticeable in both transparent and non-transparent conditions, as well as in the overall results considering both transparent and non-transparent populations.

[4]http://www.minitab.com

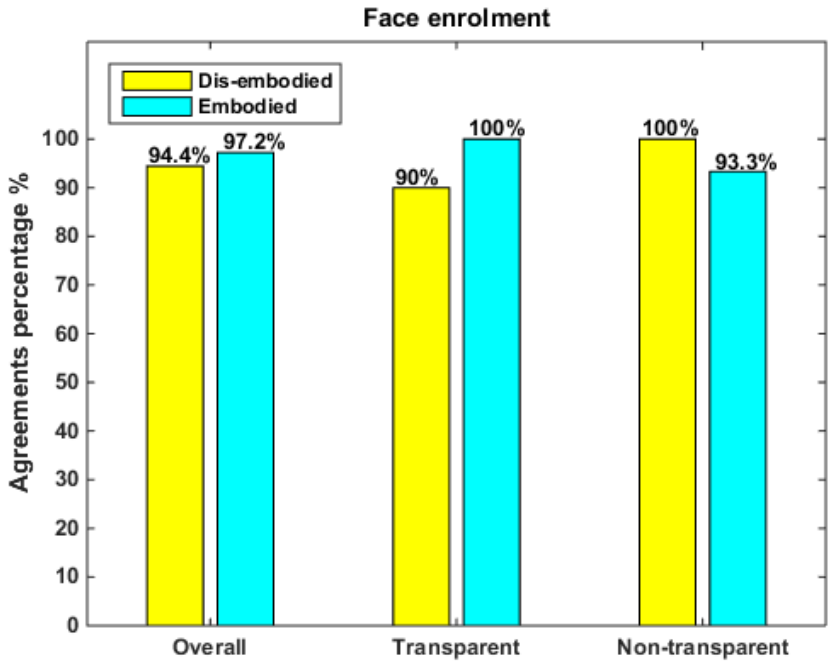


Figure 5.5: Results for the first privacy check (face enrolment)

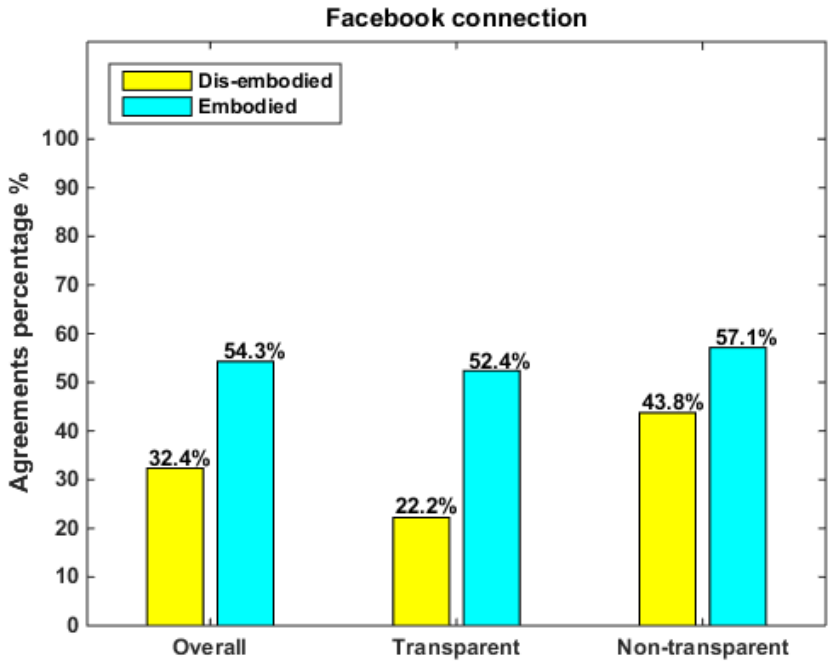


Figure 5.6: Results for the second privacy check (Facebook connection)

In order to check if the identified differences were statistically significant, the proportions of the two privacy measurements of the considered conditions were compared by using a 2 sample z-test.
First privacy check (Face enrolment). For the first privacy check no significant effects between embodied and dis-embodied systems for the overall results (p-value = .554, z-value = -0.59), transparent condition (p-value = .136, z-value = -1.49), and non-transparent condition (p-value = .301, z-value = 1.04) were found. This was aligned to expectations.
Second privacy check (Facebook connection). For the second privacy check no significant effect between embodied and dis-embodied systems for the overall results (p-value = .059, z-value = -1.89) was found. For the transparent condition a significant effect was found (p-value = .040, z-value = -2.06). Small effect sizes were for both results (respectively d = 0.22 and d = 0.32). Significant effects were not found between embodied and dis-embodied systems for the non transparent condition (p-value = .460, z-value = -0.74).
As previously mentioned, the size of the considered populations are relatively small, and this could have reduced the size of the observed effects. Specifically, it is suggested that significant effects in the overall results were not found because—as the effect size is smaller—it is necessary to use a much larger sample size to detect a significant effect. However, the preliminary descriptive results are encouraging for the hypothesis. An embodied system is capable of increasing users' risk tolerance when requiring them to provide their private information, thus reducing their privacy concerns compared to a dis-embodied system *but only significantly when the embodied system is transparent.*

A z-test for two proportions samples was again used to identify significant differences among transparent and non-transparent settings when controlling for embodiment type. No significant differences were found in the number of people giving consent to enrol their face compared to transparent and non-transparent conditions and controlling for embodiment type (disembodied condition: Z = 1.49; p = .136; embodied condition: Z = -1.04; p = .301). Similarly, no significant differences were found in the number of people giving consent to connect to their Facebook account when comparing transparent and non-transparent conditions and controlling for embodiment type (disembodied condition: Z = 1.36; p = .173; embodied condition: 0.28; p = .781).

5.3.2 Analysis of Reaction Times

The reaction time of participants was recorded on the user consent page and the Facebook request page before deciding to either agree or disagree to the face enrolment system requests. These were measured automatically by the system interface in seconds. Techni-

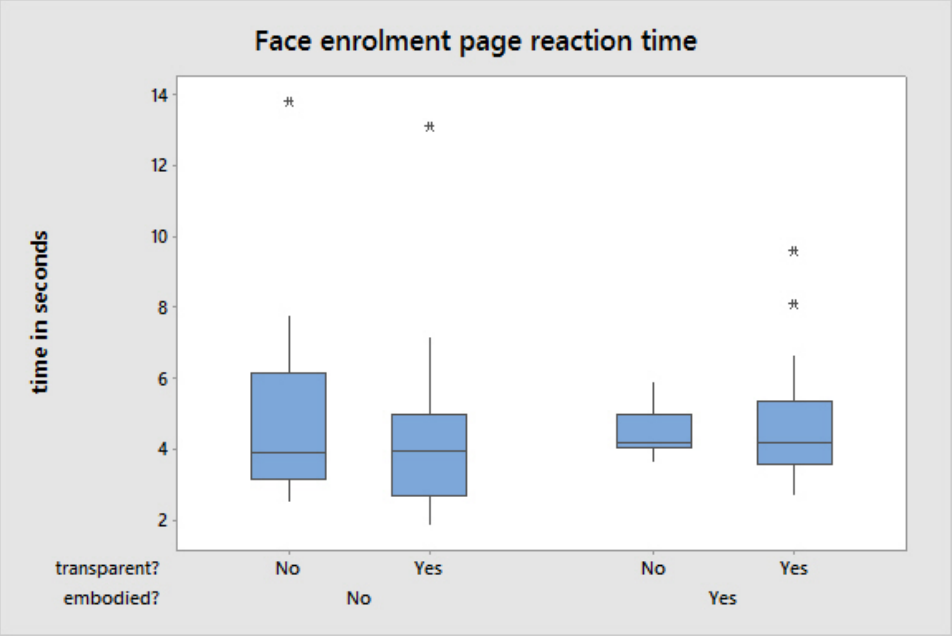


Figure 5.7: Reaction time after asking users consent to face enrolment.

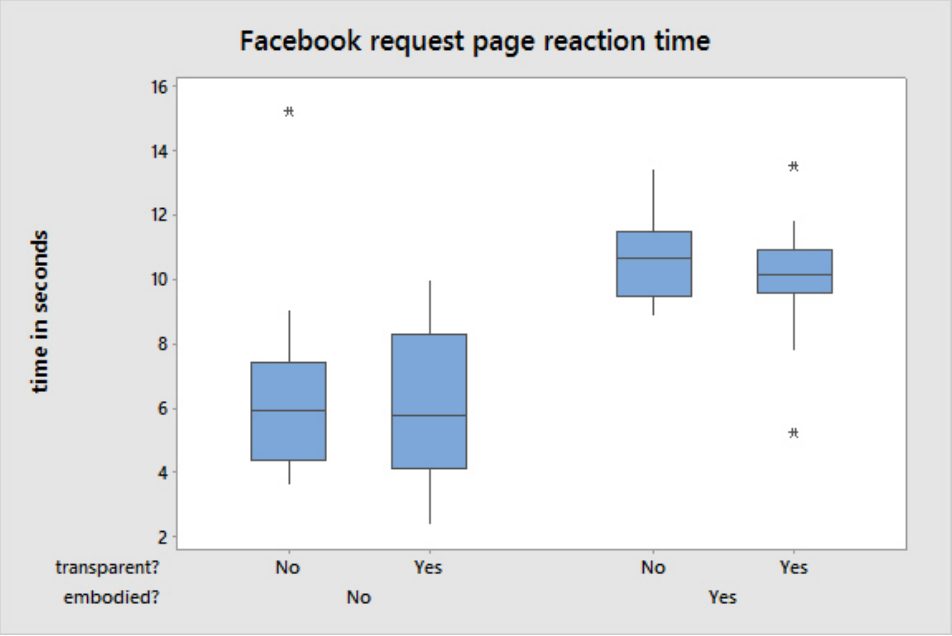


Figure 5.8: Reaction time after asking users to connect to their Facebook account.

cal difficulties prevented the recording on the physical drive of the reaction time for three participants during the embodied-transparent condition. Thus, these participants were excluded from this analysis. A two-way ANOVA was used to compare the differences in means for the reaction times among the two considered factors: embodied/disembodied and transparent/non-transparent.

Figure 5.7 shows the reaction times among the four different conditions for the user consent page, whereas Figure 5.8 shows the reaction times for the Facebook request page. For the user consent page, there were no noticeable differences between conditions. However, for the Facebook request page, a dramatic increase in the reaction times during the embodied settings compared to the disembodied ones was found. Indeed, when considering the reaction times on the user consent page, main effects for both embodiment ($F(1,65) = 0.05$, $p = .820$) and transparency ($F(1,65) = 0.02$, $p = .885$) were not found. Similarly, no interactions effects were found ($F(1,65) = 0.42$, $p = .518$). However, when considering the reaction times on the Facebook request page, a main effect for embodiment was found ($F(1,62) = 61.31$, $p < .001$) but no effects on transparency ($F(1,62) = 0.53$, $p = .469$) or factors interaction ($F(1,62) = 0.09$, $p = .767$).

The main effect for embodiment cannot be explained by different duration of the interaction between the two considered technologies. In fact, no main effect was detected on the user consent page, which presented an interface and robot speech/gesturing quite similar to the one presented for the Facebook request page (see section 5.2.3 for a description of the interfaces).

5.3.3 Analysis of User Experience

The data collected by the UEQ questionnaire was processed with the tools provided by the authors of the questionnaire [225][5], thus obtaining transformed data for each of the questionnaire's items and the scale means per person of the six considered questionnaire's dimensions. These six responses are used as dependent variables for the statistical analyses.

An initial MANOVA analysis examined the six questionnaire dimensions as dependent variables, and embodiment and transparency as independent variables. The analysis showed a main effect for embodiment in user experience between robot and interactive kiosk ($F(5, 64) = 6.457$, $p < .001$; Wilk's $\lambda = .665$, $\eta^2 = .34$), a main effect for

[5]Please refer to http://www.ueq-online.org/ for related details and data analysis tools.

Table 5.3: Summary of the follow-up univariate ANOVA analyses on each UX dimension.

	Embodiment				Transparency				Interactions					
UX dimensions	$\mathbf{M_d}$	$\mathbf{M_e}$	**F(1,68)**	**P**	$\mathbf{M_n}$	$\mathbf{M_t}$	**F(1,68)**	**P**	$\mathbf{M_{dn}}$	$\mathbf{M_{dt}}$	$\mathbf{M_{en}}$	$\mathbf{M_{et}}$	**F(1,68)**	**P**
Attractiveness	1.032	1.532	5.32	**.024***	0.990	1.504	4.34	**.041***	0.500	1.458	1.512	1.547	3.73	.058
Perspicuity	2.146	2.292	0.44	.510	2.121	2.293	0.95	.333	2.156	2.138	2.083	2.440	1.17	.283
Efficiency	1.410	0.931	2.90	.093	1.290	1.079	0.73	.395	1.234	$1.550^{\dagger a}$	1.350	$0.63^{\dagger b}$	4.81	**.032***
Dependability	0.660	1.069	3.64	.060	0.556	1.098	6.25	**.015***	0.328	0.925	0.800	1.262	0.10	.751
Stimulation	0.542	1.319	14.03	**.000*****	0.573	1.201	6.73	**.012***	$-0.219^{\dagger a}$	$1.1500^{\dagger b}$	$1.417^{\dagger b}$	$1.250^{\dagger b}$	10.98	**.001*****
Novelty	0.160	0.931	9.85	**.003****	0.137	0.854	6.03	**.017***	$-0.734^{\dagger a}$	$0.875^{\dagger b}$	1.067	$0.833^{\dagger b}$	10.81	**.002****

Notes: M_d, M_e, M_n, M_t, M_{dn}, M_{dt}, M_{en}, M_{et} are the means during the different experiment conditions. The subscript letters d, e, n and t stand respectively for disembodied, embodied, non-transparent and transparent. *p < .05, **p ≤ .01, ***p ≤ .001. † denotes significant differences by mean of a Tukey *post hoc* test between items having different letters.

transparency (F(5, 64) = 3.169, p = .012; Wilk's λ = .802, η^2 = .20) and an interaction effect (F(5, 64) = 3.517, p = .007; Wilk's λ = .785, η^2 = .22).

Further investigated was the differences in means for the six UX dimensions (Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, Novelty) within the two considered factors using follow-up univariate ANOVA analyses. Table 5.3 summarises the results of these analyses. Specifically, it was found that the embodied system was judged to be significantly more attractive (F(1,68) = 5.32, p = .024), stimulating (F(1,68) = 14.03, p = .000) and novel (F(1,68) = 9.85, p = .003) than the disembodied system. In addition, it was found that the transparent interface was judged significantly more attractive (F(1,68) = 4.34, p = .041), dependable (F(1,68) = 6.25, p = .015), stimulating (F(1,68) = 6.73, p = .012) and novel (F(1,68) = 6.03, p = .017) than the non-transparent interface.

Finally, the interaction effects for efficiency were detected (F(1,68) = 4.81, p = .032), stimulation (F(1,68) = 10.98, p = .001) and novelty (F(1,68) = 10.81, p = .002). A Tukey *post hoc* test revealed that the embodied transparent system was judged significantly less efficient compared to the disembodied transparent system (p = .021). In contrast, the disembodied non-transparent system was judged significantly less stimulative compared to the embodied transparent system (p = .000), to the embodied non-transparent system (p = .000), and to the disembodied transparent system (p = .000). The test also revealed that the disembodied non-transparent system was again judged significantly less novel compared to the embodied transparent system (p = .001), to the embodied non-transparent system (p = .000), and to the disembodied transparent system (p = .001).

5.3.4 Conclusions

From the analyses, it was found that an embodied robot using a transparent interface can collect significantly more users' private information than a kiosk, using the very

same transparent interface. However, this effect is not significant when the two systems use the non-transparent interface. This goes somewhat towards validating hypothesis H1. It was found that **there is not sufficient evidence to validate hypothesis H2**. In fact, when comparing the transparent and non-transparent interfaces within the same system (*i.e.* robot or kiosk), there are no significant differences in the amount of private information collected by that system. Similarly, when considering the time spent by users on the user consent and Facebook consent pages it was found only a main effect for embodiment in the Facebook consent page, but neither for transparency nor interaction effects.

These are interesting results as it appears that the presence or not of transparent information on the system's interface is not the crucial feature impacting on users' privacy considerations. Indeed, it is the physical design of the system that leads to major differences in users' privacy considerations, at least in this considered scenario and application. Thus, a system having a humanoid form and human-like capabilities, such as speech and gestures, can alter the risk perception of users and facilitate the collection of more private information compared to a disembodied system. Nevertheless, this effect is only visible when the systems under comparison are providing transparent information, as required by common privacy legislation.

The analyses on user experience data **provide strong evidence in support of the third hypothesis (H3)**, namely that a transparent system leads to a more positive user experience, as compared to a non-transparent system. In fact, it was found the main effect on transparency for the six dimensions of user experience considered as a whole. By further investigating the data with follow-up univariate ANOVA analyses, it was found that transparency positively impacts the perceived attractiveness, dependability, stimulation and novelty of the system. Effects for perspicuity and efficiency were not found.

Detecting an effect for dependability dimension is particularly important for the study. This measure of user experience is related with items investigating security and predictability of the system, which is aligned with the predictions that providing additional information to users facilitates a better understanding of the system and has a positive impact on their user experience.

The lack of main effects for perspicuity was not a surprise, since the ease of use for both transparent and non-transparent interfaces was not manipulated, and the interactions required for both the robot and the interactive kiosk were the same, namely tapping on a touchscreen display.

It can be speculated that the transparent interface, providing additional information on how the face enrolment application recorded the faces to näive users, may have been perceived as more attractive, stimulating and novel, as compared to the non-transparent interface.

Finally, when the robot provided transparent information, it was perceived as less efficient than an interactive kiosk providing the same transparent information. It can be speculated two reasons for this finding. 1) This effect was due to a different touch sensitivity of the robot display as compared to the kiosk touchscreen. In fact, during the debriefing interviews, some of the participants suggested that the robot monitor was not reactive enough. 2) Participants navigating on the touchscreen and not using mixed interaction styles. The multi-modal nature of the robot may have contributed to the feeling of inefficiency, and a different interaction style may have felt more appropriate for the interaction. This factor together with the additional number of pages, and therefore taps, required by the transparent interface, may have affected the perceived efficiency of the embodied transparent system as compared to the disembodied transparent one.

In the perspective of a privacy-sensitive design approach, being able to detect these UX effects is incredibly crucial, since users' privacy considerations are an essential element in designing the considered system [326].

It is important to acknowledge that the present study does not come without some limitations. Firstly, the sample size in each group was moderate. This might have reduced the effect size and prevented significant effects between groups.

Secondly, the findings are currently limited to the present context of the study, namely a face enrolment system situated in a major corporate trusted environment. Different applications, framing contexts and types of technologies may determine different effects.

Thirdly, norms and expectations regarding privacy are considered to be culturally dependent in information security studies [102], similarly, the study may not generalise to different cultural contexts.

Fourthly, during this study, interactions with the robot were expected for the participants in the embodied condition. No one refused or avoided interacting. This may not have been the case should the robot be located in the wild, as per the previous chapter in this dissertation.

In the previous study, it was apparent that some people avoided going near the robot, and it was suggested this might be due to high perceived risk. Participants were instead invited to this study. Therefore those who accepted were possibly already people who have higher risk-taking thresholds and would not avoid a robot in the wild. Furthermore, the

sample consisted only of Facebook users and this may have impacted results. Facebook users may have different perceptions of risk and or robots, compared to non-Facebook users. Further approaches in this area would have to be considered to avoid excluding segments of the general population from analysis.

5.4 Reflections

The study scenario expected transparency might be a significant factor in reducing users' risk perception, since providing more information may possibly mitigate users concerns and increase user trust [297]. Instead, the experimental data shows the opposite trend. This trend is particularly evident in the kiosk condition, although it is not statistically significant. What these results suggest is that in the particular scenario, prominent and transparent notification of how users privacy would be protected may have been interpreted as privacy warnings. Possibly by identifying potential threats to users privacy that they may have previously been unaware of. Users' experience of entitlement to privacy rights may explain this effect: telling participants something about their rights on their personal data raises their awareness, and they then see it as important [239]. Alternatively, it may be that users privacy concern was roused by the transparent condition, as indicating a decrease in objective dangers of disclosure can lead users to be less forthcoming with information [195].

There are two major schools of thought regarding privacy and transparency in internet use. In the first school of thought, users are considered as rational agents, who perform a 'privacy calculus' that assesses privacy risks and benefits of disclosure. When properly informed, they alter their behaviour regarding disclosure to protect their privacy [22, 269, 363]. In the second school of thought, users are considered as not entirely rational; they are bounded in their rationality by cognitive limitations and decision-making bias that prevents their accounting for privacy risks. They unwillingly put their privacy at risk and are manipulable by those with high interest in collecting their information [2, 22, 38].

In the study, providing users with transparent information regarding the collection of their data did not significantly change the amount of personal information collected. Interestingly, the results raise serious questions that require further consideration regarding embodiment. While there was no significant effect on the overall disembodied vs embodied condition, the trend shows that the embodied condition was able to gain consent for more connections to Facebook, then the disembodied condition. Furthermore,

there was a significant difference when the embodied condition was transparent. These results support the school of thought that users are bounded in their rationality by cognitive bias. What may have been the reasons for this?

Firstly, it is suggested that the nature of the second privacy check, connecting to Facebook, may be considered as having specific social norms. A social norm, such as meeting and then connecting to someone on Facebook, may have seemed more contextually relevant in the embodied condition due to people anthropomorphising the robot. Anthropomorphising is when people assign human emotions and intentions [24]. A humanoid robot asking to stay in touch may appear to align with people's mental model of relevant social conventions (*i.e.* retaining contextual integrity) for a social entity, more so then a non-humanoid machine asking to stay in touch. Therefore more people were comfortable with connecting to the robot vs the kiosk. This suggests that for commercial applications if a social networking option is required by business, a humanoid robot may be a better choice than a kiosk.

Secondly, while being transparent lowered the percentage of users willing to connect, the embodied condition did not lower as dramatically as the disembodied condition. The increased privacy concern raised by the transparency condition was mitigated in the embodied condition. Transparency signals trust [253], and it may be that a higher level of trust was felt towards the robot than the kiosk. Further studies could investigate the role of trust and its effect in a robot as opposed to a kiosk.

Nevertheless, the study demonstrates that while you cannot expect transparency regarding privacy practices to increase gaining users' informed consent, you can expect a higher gain from the use of a social robot as opposed to other comparable technology. Furthermore, using a PbD approach to data collection, *i.e.* transparency, will not negatively impact the social robot application design. Taking into account the positive results regarding user experience, using transparency may, in fact, be a bonus for social robot application design.

5.4.1 Legal Implications of the Findings

The study opens a vital discussion around the topic of current privacy legislation.

Firstly, it was able to be demonstrated that the provision of transparent information to users, as required by law in a large number of important jurisdictions (*e.g.* US, Europe and Australia) may not significantly affect users' privacy considerations in the considered scenario.

Secondly, current privacy legislation does not consider the impact that the physical design of the system can have on users' privacy considerations. It has been demonstrated that the physical design of the system does significantly affect users' privacy concerns. The embodied design of a humanoid robot can mitigate users concerns and collect more private information in a transparent system, compared to a disembodied transparent system.

Given these findings, present privacy legislation may allow misleading usage of technologies. For example, businesses using technologies to provide services to users may adhere to privacy legislation by disclosing all the necessary information required by law and providing the necessary rights to users. However, they can decide to use a robot with a particular physical design and to develop specific robot behaviours with the aim to reduce users' privacy concerns. This would allow them to collect much more of users' private data compared to other types of technologies.

Therefore, it is recommended that privacy legislation take into account aspects related to the physical design of the technology and how the designed interactions of the technology may impact on users' privacy considerations.

5.5 Learnings

This study contributed to the goal of understanding social robot application design in the following areas:

1. *Using Privacy-by-Design*
   Following privacy best practice with a PbD approach may produce different results in social robot applications as opposed to other comparable technologies. People may provide more information to a social robot. While being transparent may lower the number of people willing to provide information, it is not to any remarkable extent. Therefore, even though PbD can be considered a useful tool for protecting privacy in social robot application design, awareness must be kept regarding the possible ramifications of this effect, both positive and negative. People may be more trusting of sharing information with a robot then may be advisable, and this may lead to unsafe directions in data collection.

2. *Privacy and the User Experience*
   A significant advantage of using PbD is in regard to the user experience. Being

transparent led to a more positive user experience. This is an exciting finding as it provides further justification for designers to promote PbD in their organisations.

3. *Application considerations*
   Privacy impacts were understood by firstly identifying the data that was appropriate to collect in the considered environment and data that was not ordinarily appropriate to collect. This is in line with Nissenbaum's contextual integrity theory [287]. Future application developments may benefit from a more structured process regarding this identification of information flows, especially during the conceptual stage of application design.

5.6 Next Contribution

The learnings from this experiment allowed sufficient practice-led research, based on theory regarding privacy and UX, to formalise the understanding of the problem space being investigated. In the next section, these learnings are combined with the previous experiment to provide a conceptualisation of the problem space.

CHAPTER 6

POSITIONING THE UX-HRI FRAMEWORK

"In other words, human-robot interaction is not 'a human playfully pretending to perform a social action towards a robot,' but 'a robot simulating the performance of a social action towards a human.'" Johanna Seibt [344, p. 393]

Chapter Summary *Conclusion to the Action Design Research (ADR) Stage One: Problem Formulation and conceptualisation for moving to ADR Stage Two: Building, Intervention, and Evaluation.*

Purpose *Identification of the problem space and positioning of the UX-HRI conceptual framework*

Methodology *Action Design Research: Reflection and Learning. Conscious reflection on contributing theoretical bases and knowledge created from the previous, practice-inspired research, to formulate the identification of the problem space.*

Findings *ADR Stage One discovered social robots should be transparent in communications for good privacy practice. This has positive effects on the user experience. Tasks or roles for the robot should be more than can be provided by a human. This may be achieved by a design space perspective catering for the tri-fold nature of social robots, as social agents, as interactive media and as communication mediums, positioned in the physical, digital and social environment. It is proposed the human-centred design approach of Lean UX, and incorporating Privacy-by-Design, may, together with the design space perspective, enable socially responsible design.*

As described previously in Chapter 1, the primary purpose of this research is to provide a practical framework for research organisations, institutions and businesses to discover, design, develop and implement socially responsible applications for social robots in public spaces.

In this chapter, I firstly conclude Stage One of the Action Design Research process, with 1) drawing the conclusions from the combined findings of the previous two experiments, described in Chapters 4 and 5, that robots should be transparent and more than human, and 2) providing the conceptualisation of the problem space.

Secondly, I identify the contributing theoretical bases from which to move forward, defining the social robot application design space for the proposed framework. This design space is based on the combined reflections and learning of Stage One: a perspective of social robots as social agent, interactive media and communication medium that inhabits the physical, social and digital realms. It is with this perspective regarding social robot application design that I then position the design methodology within a human-centred design framework.

Human-centred design (HCD) is a comprehensive design framework, yet does not explicitly include privacy methodology as a core component. From the investigations exploring privacy and the user experience, I hence include the Privacy-by-Design approach within this methodology and combine it with the HCD approach of Lean UX, incorporating the two within the framework design. This presented framework is then integrated with the latest in social robot theory and *a posteriori* knowledge from Stage One. This chapter, therefore, effectively describes the scaffolding upon which the proposed UX-HRI framework is based.

6.1 Conclusion: Be transparent and more than human

Vital understandings were gained from the Stage One investigations. Comprehending the issues of social robot application design through practical experience provided direction on dealing with the unknowns when using a commercial social robot platform in a public or publicly accessible space.

In Chapter 4 it was discovered a social robot could function as effectively as a human in the considered task of giving away samples. However, deploying the social robot entails great difficulty, and the effectiveness of the robot in the study may be a result of initial novelty. Therefore, to justify the cost of a social robot, applications that utilise the greater

capabilities of the robot as compared to a human, specifically digital integration, will provide the most value for organisations.

Furthermore, it was observed that people behave in a social fashion with the robot and people's social behaviour evolves in a mutual shaping fashion with the people interacting and surrounding the robot. Hence, in answer to the research question *"To what extent can a robot perform a task requiring social engagement as well as a human?"* we can answer that the robot is effective, however the surrounding humans influence the extent of effectiveness in the interaction of consideration.

In Chapter 5, the preliminary online survey [397] indicated the importance of the situated context, and the effect on privacy considerations in interactions with a social robot, strengthening the significance of Contextual Integrity (CI) theory [286]. From the experiment, it was discovered people provide information to a social robot slightly differently to other technology (a kiosk). Transparency in a task that raised privacy concern was found to affect the user experience with the social robot positively. The social robot also was able to facilitate the collection of private information to a greater extent than a kiosk. Thus, *"Does transparency affect user experience for social robots?"* is answered yes, and to the positive. To answer the research question: *"What is the effect of embodiment on privacy considerations?"*, the study discovered that people might be more willing to provide social information to a social robot.

Thus, with the initial research questions providing further clarity regarding potential social robot applications, privacy and UX, I move onto conceptualising the problem space in the following section.

6.1.1 Conceptualizing the Problem Space

What the two exploratory experiments have enabled is a conceptualisation of the problem space, via Practice-Inspired Research and Theory-Ingrained Artifact [346]. Synthesis occurred organically or was distilled in the ongoing team meetings during the experiments. It is not clear from Sein *et al.* [346] exactly how this conceptualisation should be expressed. Therefore I articulate the conceptualisation as below, using Maedche *et al.*'s [251] conceptual model of the problem space from Design Science Research, with the four key concepts: stakeholders, needs, goals and requirements.

Stakeholders: Stakeholders are divided into two types, Primary and Secondary. Primary stakeholders for this research are:

1. Organisation, Business, Institute, who are the owners of the robot

2. Practitioners, or employees within the organisation who deploy the robot

Secondary stakeholders are:

1. Co-employees, people who may be performing their tasks in conjunction with or alongside the robot, robot interaction may be direct or indirect, co-located or distant (collaborators/ team members/ teammates/ collaborator employees)

2. End users, people who are actively interacting with the robot (consumers/customers/clients)

3. Bystanders, people who are not interacting with the robot. They may require some understanding of, or be affected by what the robot is doing, in the considered environment.

Needs: The needs are based on the primary stakeholders for the project.

1. Potential applications for social robots, especially those that justify the expense of purchase and maintenance

2. Methods for human-centred design with social robots that ensure privacy and UX best practice

3. Methods for development that allow business practices such as agile development and quick turnarounds of prototypes for testing

4. Methods for deployment that ensure a holistic fit within the deployment environment and enhance customer experience

Goals: These are re-iterated as a dual item of my research and the larger research project

1. To discover potential opportunities and use cases for social robots

2. To uncover challenges of implementing social robots (both technical and social) and possible methods to overcome them

3. To successfully design, develop and implement prototype, socially responsible social robot applications

Requirements: These are based on both the organisational values and needs, researcher and practitioner's experience, and HRI literature. In particular, taken from the literature—the code of ethics put forward for the human-robot interaction profession by Riek and Howard [315]. Riek and Howard's code of ethics provides principles for both hardware design and software design of robots. The salient points for the software design of social robot applications have been extracted, included and extended in the following requirements. However, it should be noted that there is no provided mechanism by which the ethics principles proposed by Riek and Howard are to be implemented. Hence this UX-HRI framework makes a step towards that direction by providing suggested mechanisms, presented later in Chapter 10.

1. Any social robot application is designed and developed to function in a commercial manner for deployment, using today's technology and capabilities. This means no Wizard-of-Oz techniques, no robot operator controlling and assisting interactions.

2. The application must be able to be used without human guidance. It has to be designed in such a way that end users can intuitively, or with guidance from the robot, make sense of how to use the application.

3. Any sensing or processing must be done as much as possible on-board the robot without the use of auxiliary equipment that would not be present in a real world deployment of the technology.

4. Any Artificial Intelligence systems used must provide a sufficient confidence and accuracy to be able to sensibly guide any decision making required by the robot.

5. Repeatable and consistent functioning is expected at all times that the robot is deployed for use with end-users. There shouldn't be any bugs in the software. Any unexpected malfunctions or lack of capability by the robot will be managed in a fallback or graceful degradation manner.

6. All functionality will meet privacy legislation requirements.

7. Finally, the value the robot is intended to provide to stakeholders (users) is real, based on genuine need. There should be a real world benefit to the task the robot is performing.

The nature of the above requirements positions them to be used, in fact, as fledgling design principles. Design studies can be undertaken with these principles as a starting

point, and work to discover the mechanism to realise them. Additionally, the Stage One investigations have provided a perspective or lens, through which to view and structure the social robot application design space. Lens being understood in this case as *"something that facilitates and influences perception, comprehension, or evaluation"* [265].

6.2 The Social Robot Application Design Space

Before any design begins, it is necessary to understand and define the design space in which the robot will be operating. Design spaces are used to understand which elements in the structure of a product must be considered and can be varied, while also providing scaffolding for construction and analysis [250]. HRI research generally positions social robots within a human-robot interaction space. Previous design spaces have been provided as taxonomies, for example by Yanco and Druery [426] and Fong *et al.* [125]. These have served well as the design aspects to consider. More modern design space examples can be seen in recent literature, for example, the design space for social, expressive cues in HRI provided by Deng *et al.* [98] and, even more recently, by Baraka *et al.* [21].

In fact a seven dimensional framework has been actively described by Baraka *et al.* [21], who effectively define a design space for characterising social robots. Social robots are positioned within a *human-robot-interaction-context*, with *robot* categorisation according to *appearance*, bio-inspired, artifact shaped and functional; *social capabilities; autonomy and intelligence*. *Context* includes the *purpose* and *application* area, *interaction* the *proximity* and *temporal profile*.

The idea of viewing social robots as occupying more than just the human-robot space is also explored by Höflich [178], where he suggests robots are in fact within a triadic model of *human-robot-environment*. This dissertation is not intending to expand Höflich's conceptualisation. However, it uses it as an inspiration to develop a perspective from which to understand social robot positioning in the design space. Höflich's views are also similar to those by Keay [206] who describes social robots as a medium for human-human interaction. Humanoid social robots as a medium of communication are argued by Zhao, who states *"humanoid social robots belong to a special type of robotic technology used for communicating and interacting with humans"* [427, p. 401]. Additional positioning of the social robot in this extended viewpoint, and incorporating the idea of the environment (public space), are put forward by Fortunati who posits that *"robots are media that serve many interactive purposes in public spaces"* [129, p. 1].

Taken together, these viewpoints stress the placing of the robot in the social sphere as a *social agent*. Furthermore, it is a placing of the robot that crosses into the digital world, suggesting that humans have a relationship with the robot as a *communication medium* but also relationships via the robot as the medium. These viewpoints additionally place the robot as an *interactive media*, where humans and robot both take a role in the non-linear interaction, co-creating the physical interaction experience. This is a vital understanding for the UX-HRI framework and, in line with formalising the design space for the methodology, I further describe this thinking in the following section and provide a visualisation of the design space for a social robot.

I believe it is necessary to categorise these three different perspectives separately to ensure each receives due consideration when designing the social robot application. The concept of the tri-fold lens is the combination of the three perspectives: social agent, interactive media and communication medium. Using this tri-fold lens allows the robot's greater capabilities to be fully considered in the innovation process. I propose that explicitly designing for the greater capabilities of the robot, with regards to this tri-fold perspective, extends the possibilities of applications and experiences that the social robot may provide and hence corresponding acceptance and longevity.

6.2.1 Social Robots as Social Agents

Social robots are treated by humans as social agents and we should build and design the social interactions accordingly. Humans are essentially social creatures, and this is a contributing factor to our intelligence [108]. This sociality we have ingrained in our makeup even predisposes us to assign human characteristics to non-human beings and artifacts. This is also known as anthropomorphising and has been suggested as a method by which we may predict or explain other agents (non-human) behaviour. It also occurs when we lack social connection to other humans [113]. This disposition to anthropomorphise is also displayed when humans interact with robots and may be further accentuated in the case of humanoid social robots, due to their human-like morphology and attributes[432]. Learning how to use technological agents additionally appears to be aided by our anthropomorphising of them [113]. As such, when we consider a robot, we may appear to unconsciously assign it as a social entity in our mental model of the world. Therefore, when considering the design space formalisation, it may be proposed that this perception can be used by designers to shape the robot behaviour.

In contrast to the anthropomorphism viewpoint, according to Becker [29] and Höflich [178], it is of greater consideration the role the robot plays in social networks, its skills

and function in social relations, rather than the anthropomorphising that occurs. People's appraisals of robots are influenced by other's interactions with it [350]. As Höflich states *"the meaning of the robot is not negotiated with the robot as social entity, but together with others in a process of continuous reciprocal indication."* [178, p. 43]

Humans treating robots as social agents is a view taken by Seibt *et al.* with the Integrative Social Robotics Framework: *"so-called 'social robots' simply are not things or instruments that people use—robots are treated as social agents, albeit most peculiar ones."* [345, p. 126]. Furthermore, as Seibt *et al.* explain, social robots may be categorised as *"...systems of affordances for social* interactions,"* and software design should be with the mindset that it is, in fact, designing of new social interactions. Hence, for defining the social robot application design space I also specifically highlight the social functionality the robot brings to an environment and the impact on the network of relations and social interactions within the said environment, going beyond relying on a simplified anthropomorphic viewpoint of a robot being a social entity because it is viewed with a social mindset.

Based on the findings of the first experiment conducted in the shopping centre and the literature given, it may also be suggested that for social robots in public spaces, it is a transient assimilation of the robot as a social agent.

Baraka *et al.* categorise social robots in public settings, such as malls and museums, as *"Robots for public service"* [21, p. 18], describing the nature of their interactions as of short duration and across a possible vast number of people of varying abilities. The time-span of use by humans is typically very short-term. Hence, the interaction must be as intuitive as possible with minimum time required for human understanding. Using this perspective with regard to time, as a method to then design and develop social robot applications, is key to ensuring the considered social actions for a task.

6.2.2 Social Robots as Interactive Media

Human-robot interactions with social robots must also include consideration of the digital interactivity that is co-created and dynamic. People understand digital information kiosks as interactive media [279]; however, this is also implicitly the case with humanoid social robots, such as the REEM and Pepper robots. Interactive media may be considered as any media that responds to people. People can be active participants in interactions with social robots. A social robot can interact via voice and gestures with people, with text, images and video concurrently displayed on its touch screen. This generally can take the form of a non-linear interaction, determined both by the human actively directing

the interaction or by the robot directing—choosing the next action based on the human's responses (or lack of). Hence, the interaction experience can be seen to be co-created and dynamic. The digital actions that can be performed by the robot all form part of the interaction experience and need to be specifically designed for, in line with the purpose of the intended application. Hence I call them out for the design space. Incidentally, this highlights the importance of interdisciplinary teams for social robot application design, for example requiring tablet user interface designers, mobile app designers and video display specialists.

It is precisely the ability of the social robot to function in a digitally interactive manner that enables applications beyond the simple substitutions of human capability. Hence it is vital to include this perspective when designing social robot applications.

6.2.3 Social Robots as Communication Mediums

The final area I define for the design space is the use of the robot as a communication medium. In this sense, communication medium is defined as a means for conveying communication *or* meaning to people. Social robots can be used as the medium through which we can talk to people at a distance, such as with telepresence; receive a virtual, but also in real life, hug from a friend via the robot; and video conferencing—which can include large audiences in multiple locations.

Additionally, a social robot can act as a "master communicator" to surrounding technology. For example—the robot may cast a video to nearby TV screens to display a video. It may send voice alerts to virtual assistants to summon assistance; or send texts and emails to a mobile phone, or a mobile phone app of the person it is interacting with or to others. I emphasise that this is called out separately to interactive media to ensure its due attention in the design space formalisation.

To illustrate an example of how this tri-fold perspective of social robot application design may be realised in a public space, I provide the following scenario:

A man arrives at a publicly accessible, privately owned, serviced office space. He is greeted by a social robot and welcomed to the location (*robot as a social agent*). The robot informs him that he can rent locker space to protect his valuables while using the office space. The man agrees he would like to do this and the robot assigns him a locker number (digitally updating the locker system in the backend) while also sending (via Bluetooth or other over-the-air protocol) him a PIN and payment option for the locker to his mobile. The robot then verbally provides directions to the locker room while concurrently displaying a choice of a video of how to get there, aiding navigation. The

man chooses to watch the video (*robot as interactive media*). The robot asks if the man is attending any meetings in the location and informs him on confirmation, there is a message for those attending the particular meeting. The robot plays the video message from the meeting organiser, who welcomes him to the office space and is followed by an advertisement for a free coffee at the cafe (*robot as communication medium*). The robot then asks if the man would like the free coffee and again sends to his phone a voucher number for claiming the coffee at the cafe, while also sending the details to the cafe system. The robot asks if it can provide any further assistance, before indicating with a gesture the direction of the cafe for him to receive his coffee.

6.2.4 Social Robots at the intersection of the physical, digital and social realms

Using the above scenario, it is readily apparent to understand the situating of the social robot at the intersection of the physical, digital and social. This idea was observed in action during the study at the Shopping centre, Chapter 4, where people interacting with the robot co-created their physical interaction experience by taking selfies and posting them online to social media. This concept of robots at the intersection of the physical, digital and social realms has been explored by researchers in the service industry, where it is described that *"the customer experience is formed by choosing elements from each realm"* [37, p. 799] with the choice made by the consumers. As such, for social robots in public spaces, it is clear that the considerations for the design space must include the realms of the physical, social and digital. The robot can be seen as bridging the physical world to the digital, and all the co-creation interactivity experiences this involves, while also being a physical agent in the social sphere. This proposed, tri-fold perspective positioning social robots in the human-robot-environment is visualised in Figure 6.1.

6.2.5 Design Approach using the Social Robot Design Space

Now that the design space is established, the design approach for the social robot application can be determined. Three broad design approaches have been recently described by Baraka *et al.* [21] for social robotics. They are:

1. Human-centred design. This positions robots as a technology that are adapted to humans and utilise humans social communication modalities.

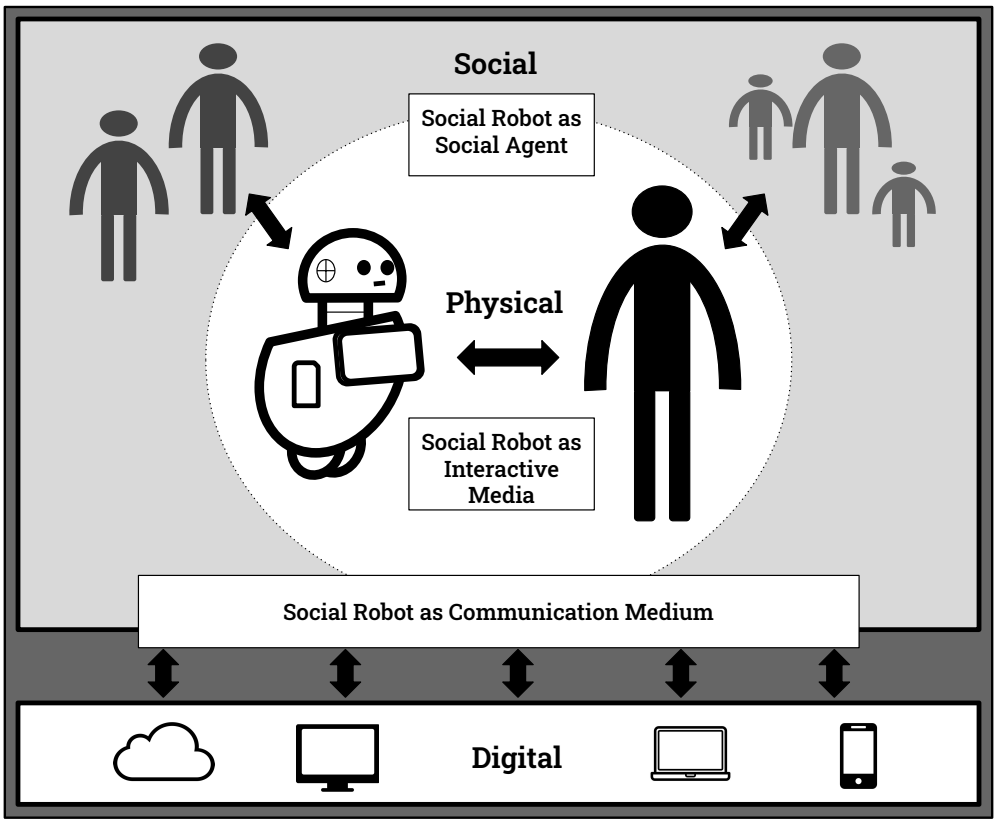


Figure 6.1: The design space perspective for social robots in public spaces

2. Robot-centred design. This positions robots as goal-oriented technology that humans may have to learn how to use.

3. Symbiotic design. This positions robots as symbiotic embodied agents and takes a holistic view that centres on the overall system behaviour, as a function of robots, humans and the environment.

This research investigates explicitly social robot applications for commercial social robot platforms of humanoid appearance. As such, it is placed within human-centred design. However, according to the above design approaches, symbiotic design considers the robot within the human-robot-environment space, which is where the tri-fold perspective of social robots for this dissertation has been set. Therefore, it could be said that the design approach followed is human-centred design with a holistic, environmental focus.

6.3 Human-Centred Design

Human-centred design (HCD) is a well-established methodology used in academia, industry and government that provides techniques and activities to identify insights, opportunities and directions from the people who may use a product, system or service, to inform its design [141, 143, 267, 367]. It is defined by the International Organization for Standardization (ISO) with the ISO 9241-210:2019 as follows:

"Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance." [185]

This definition includes the note regarding usable systems: *"Usable systems can provide a number of benefits, including improved productivity, enhanced user well-being, avoidance of stress, increased accessibility and reduced risk of harm"*. It is the area of enhancing well-being and avoiding stress that is of special interest for human-robot interaction with social robots in public spaces. Social responsibility requires ensuring the impact of a product or application is of benefit to society, enhancing well-being. Hence, with human-centred design the goal of designing socially responsible social robot applications can be met.

6.3.1 Principles of HCD

The HCD ISO standard is *"intended for use by those responsible for planning and managing projects that design and develop interactive systems"*, and states *"a human-centred approach should follow the principles listed below:*
1. The design is based upon an explicit understanding of users, tasks and environments
2. Users are involved throughout design and development
3. The design is driven and refined by user-centred evaluation
4. The process is iterative
5. The design addresses the whole user experience
6. The design team includes multidisciplinary skills and perspectives"

Accounting for the whole user experience (Principle 5) is an important consideration. The majority of research in social robotics generally only takes into account the user

experience with a single user and context. I put forward that the customer experience, which is across all user interactions over time, is in fact of more relevance when designing a social robot application for public spaces, due to the ever-changing environment, short duration's of interactions and flow of people in the shared space.

Relevant for social robots in public spaces is Principle 1, which describes *"Products, systems and services should be designed to take account of the people who will use them as well as other stakeholder groups, including those who might be affected (directly or indirectly) by their use...The characteristics of the users, tasks and environment are called the context of use...The context of use is a major source of information for establishing requirements (see 7.3) and an essential input to the design process."*

The HCD ISO standard also states that *"taking a human-centred approach results in systems, products and services that are better for the health, well-being and engagement of their users, including users with disabilities."* Accounting for users who might be affected directly/indirectly by use of a social robot is of vital consideration when the robot is placed in a public space. For example, recent trial implementations of grocery store robots in Woolworths shops in Sydney, Australia, have affected the psychological well-being of the people in the store. A woman with disabilities reported her guide dog being unrecognised by the robot, and referred to as an 'obstruction' by the robot, making her feel uncomfortable with the robots presence [109].

Essentially, human-centred design is an alternative to the more narrowly focused user-centred design (UCD) approaches [141, 143, 367]. HCD may be considered a concern for people, whereas UCD focuses on people's *roles* as users [367]. Additionally, UCD's focus does not account for social context, which HCD incorporates [141]. This narrow focus and the need to broaden the scope beyond the user was articulated in a 2009 interactions article by Schweikardt, who described UCD as *"an incomplete philosophy that lacks a sense of responsibility for concerns other than those of the immediate end user."* [343, p. 12]

6.3.2 HCD as support for Human Rights and Human Dignity

The HCD concern for (all) people is reflected in the philosophical stance of HCD scholar Richard Buchanan, *"Human-centered design is fundamentally an affirmation of human dignity. It is an ongoing search for what can be done to support and strengthen the dignity of human beings as they act out their lives in varied social, economic, political, and cultural circumstances."* [52, p. 37]. Buchanan puts forward that human rights and human dignity are the first principles that design is grounded in, and any work should

be carefully considered for how these principles will be affected. Following this stance, a human rights and human dignity perspective has also been called for in the related field of Technical and Professional Communication (TPC) [403]. Privacy is a fundamental human right and a pillar of human dignity [123] and as Floridi states, in reference to the European GDPR:

"The protection of privacy should be based directly on the protection of human dignity" [123, p. 308]

Privacy is a stated area of focus in this dissertation. Hence HCD, with its stated support of human rights and human dignity is an appropriate design framework to use as a basis for social robot application design. However, HCD does not explicitly call out how to protect privacy, so a method for doing this is required.

6.4 Protecting Privacy in HCD with a Privacy-by-Design Approach

Privacy-by-Design was put forward by Ann Cavoukian as a method for ensuring consideration of privacy occurs at all stages of development [62]. Privacy-by-Design (PbD) promotes the integration of privacy considerations into the design and development process from the very beginning of a project. PbD incorporates the following guidelines:

1. Proactive not Reactive, Preventative not Remedial
2. Privacy as the Default Setting
3. Privacy Embedded into Design
4. Full Functionality — Positive-sum not Zero-sum
5. End-to-End Security — Full Lifecycle Protection
6. Visibility and Transparency — Keep it Open
7. Respect for User Privacy — Keep it Open

A vital step for consideration in the above is Transparency, as in how data is collected, used and shared. Transparency is both an essential component of Privacy-by-Design but additionally good business sense as well [415]. Culnan and Bruening suggests that transparency must be carefully applied and developed as part of a system design process,

not as a separate task performed by a legal team at a later date. Privacy notices should be disclosed to individuals at appropriate moments, and provide relevant information in an understandable language, suitable for easy comprehension [82]. However, as was discovered in the experiment regarding privacy and transparency, embodiment played a role in the amount of information a person was willing to provide to a social robot. A humanoid social robot providing transparency of information practice can alter the risk perception of users and collect more information than a disembodied system. Hence for social robots, the manner in which information is presented and collected must be carefully assessed. People may place societal expectations on disclosed information, due to it being provided in a contextual "social" interaction. This lends itself to the idea of privacy impacts being assessed by the effect on contextual integrity. As such, contextual integrity is a vital consideration for social robot application design and requires further investigation.

While Privacy-by-Design provides vital guidelines, there is a gap in the actual methods required for social robots to follow the guidelines. One way to ensure privacy is a consideration within the development process is by conducting a Privacy Impact Analysis (PIA)[1] on the proposed application. This may allow identification of privacy issues to be considered and risk management strategies applied. However, this can be difficult to apply to a social robot, especially when an application is still in the conceptualisation stage of development. Another method is using the seven types of privacy [120], which can provide a lens through which to view the possible privacy impacts and protections required. This has been argued as a valid approach in determining domestic surveillance issues with drones, due to its wide-ranging applicability without allegiance to any singular privacy definition [191]. The seven types of privacy are defined as the following:

1. Privacy of the Person
2. Privacy of Behavior and Action
3. Privacy of Communication
4. Privacy of Data and Images
5. Privacy of Thoughts and Feelings
6. Privacy of Location and Space

[1]For example, https://www.oaic.gov.au/privacy/guidance-and-advice/guide-to-undertaking-privacy-impact-assessments/

7. Privacy of Association (including group privacy)

Using the seven types of privacy in social robotics has also just recently been suggested by Heuer *et al.*[173] who suggests using a Risk Management based process, based on the seven types. Risk Management relies on managing the knowns and unknowns in a situation [66]. As can be seen from the Stage One experiments, social robots present their own, unique challenges, differently from both humans and other technologies, and there is a large number of unknowns. More importantly, there is a large number of unknown unknowns for social robot deployment, as social robots are not yet common nor pervasive throughout society. While methods have been presented for dealing with unknown unknowns [307], it is still not possible to completely imagine all possibilities.

Another option suggested in dealing with social robots and privacy considerations is to preclude specific actions [130], however this may be unnecessary if privacy management can be designed into an application as default. Furthermore, suggestions of social robots having 'poor memories' for remembering people, to meet socially acceptable standards of privacy, still require practical guidelines for implementation in real world applications.

Differently to Heuer *et al.* [173], I suggest that the seven types of privacy are used in conjunction with Nissenbaum's Contextual Integrity (CI) [286] approach, which allows consideration of the situated context, including the nature of the public space environment. This pairing has been suggested previously, in the context of ethical domestic drone surveillance [191]. By maintaining contextual integrity and following socially responsible and inclusive design, it may be possible to avoid triggering privacy concerns and intrusions of privacy. This is investigated further in Design Study 2 (Chapter 8).

Taking the above together, it is clear we can use HCD, with a Privacy-by-Design approach, to support human dignity and human rights in social robot application design. However, there are many different approaches to HCD and the approach selected for use in this research is described in the following section.

6.5 A HCD approach for UX-HRI

There are multiple approaches used by researchers and practitioners in HCD. Six approaches were identified in 2011 by Steen: participatory design, ethnography, the lead user approach, contextual design, co-design and empathetic design [367]. Participatory design is a popular choice in the HRI field, with several studies using it due to its suitability for vulnerable groups [18, 229, 419]. However, it is not clear from these studies how to avoid limitations on innovation from users habituated to current technology.

Furthermore, a criticism of HCD is its focusing on usability and not usefulness [289]. Usefulness has been identified as a vital factor in social robot adoption [96]; therefore, approaches must be carefully considered as to their ability to discover a useful social robot application.

In the last few years, other approaches in HCD have been identified that involve Design Thinking. Design Thinking is a human-centred approach to innovation. Tim Brown, the CEO of organisation IDEO, explains *"It draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.....It lets people find the sweet spot of feasibility, viability and desirability while considering the real needs and desires of people."* [49]

Given one of the stated goals of this framework is discovering social robot applications that are suitable for businesses, Design Thinking is an obvious choice. The advantage of Design Thinking is that it incorporates designing for the user experience from the beginning. As described by Robert Reimann, Past-President, Interaction Design Association (IxDA): *"The core elements of design thinking are solving problems creatively to provide solutions that put humans and good user experience first..."* [360]

HCD with Design Thinking matches the needs of business and innovation with solutions that people will actually use. However, to reach the stated UX-HRI goal of discovering, designing, developing and implementing social robot applications, a development method that is able to use this approach is required.

Traditional development practices such as the Waterfall method [305] struggle to cater for the iterative cycling required for Design Thinking. Instead, a now widespread practice in business organisations is the iterative approach of Agile development [1, 170]. I suggest this method may also be particularly suited to robotics, due to its (not always acknowledged) use in Robotics competitions such as Robocup [300].

An approach for HCD that meets both of these requirements is that of Lean UX, which combines Design Thinking, Lean Start-up and Agile practices to create optimum user experiences and business benefits.

6.5.1 Lean UX

Lean UX can be thought of as a way to apply iterative methods to user experience design. It aims to reduce unnecessary UX documentation and provide value by ensuring you are designing something people are actually going to use. In essence, Lean UX allows combining the solution-based approach of design thinking with the iteration methods of which Agile is composed. The idea of Lean UX is to build a shared understanding of

the actual product experience being designed. Developers participate in parallel with designers to achieve contextual understanding together, which frees up the need to lead by documentation, common in the standard UX process. [151]

As discussed in the literature review of Chapter 2, UX in HRI suffers from a lack of business perspective in the UX design of social robot products [8], which may be easily addressed by using Lean UX. Additionally, Lean UX incorporates the analysis, design, implementation and evaluation required for UX processes also stated as lacking in HRI. Furthermore, by using Lean UX, it removes the need for unnecessary UX documentation, by synthesising and integrating the necessary experience into the actual realisation of the product prototype. Documentation not pertaining to the final product is deemed unnecessary. Through a shared understanding of the situated context and the unmet user needs, by both developer and designer, a shared vision is enabled, allowing a clear business goal to be achieved. In fact, Lean UX allows the transition away from the trope of creating sometimes arbitrary user experience goals that "delight the customer", yet are useless in meeting business goals such as retaining customers' loyalty [103]—by providing services that are actually useful for both user and business.

Using the Lean UX HCD approach may guarantee a social robot application that fits well with its environment, stimulates positive UX for people while also meeting people's needs with a useful application and providing business value. This approach is expanded upon and investigated in the next Chapter.

6.5.2 Bringing it all together for UX-HRI

Hence, the design approach put forward in this framework brings together PbD and Lean UX HCD approaches into the Social Robot Design Space. It involves:

1. Following the six HCD principles, especially accounting for the public space environment and customer experience design

2. Using the HCD Lean UX approach

3. Using Privacy-by-Design (following the philosophical commitment of HCD to Human Rights and Human Dignity)

4. Using the Social Robot Design Space and catering for the tri-fold nature of social robots as social agent, communication medium and interactive media, positioned in the physical, digital and social environment.

6.6 Next Contribution

This and the previous chapters have documented the greater understanding regarding social robot application discovery, design and development that has occurred. The issues to be considered in deploying robots in the wild and ramifications from following business best practice in privacy and UX design are still to be solidified. With this articulation of the problem space and the proposed UX-HRI framework, it is possible to move confidently to the next stage.

In the next and following contributions, the knowledge gained is expanded with the deployment of a social robot in busy, shared public spaces. Working closely with business, the first steps towards confirming the UX-HRI framework for discovering social robot applications that are privacy-sensitive, foster positive user experiences and provide value to end-users, employees and organisations responsible for deploying the robot, are made.

Part III

Building, Intervention and Evaluation

CHAPTER 7

SOCIAL ROBOTS IN COMMERCIAL APPLICATIONS

"The design challenge is to create a hybrid that invites people to emotionally interact (through having traits of 'beings'), but at the same time clearly communicates its 'being different'." Julika Welge and Marc Hassenzahl [410, p. 995]

Chapter Summary *Design Study 1: Designing the UX for HRI. Location: Sydney International Airport. My Role: Researcher.*

Purpose *Undertake the exercise of identifying, designing, developing and implementing a social robot application with a commercial organisation in a complex public setting.*

Methodology *The conceptual framework of Lean UX combined with HRI research, is used to discover potential applications that could enhance the customer experience at the airport.*

Findings *The process is used successfully with the organisation to develop and trial a social robot application in the complex airport environment.*

Contributors *This chapter incorporates the work and findings produced in collaboration with: Jonathan Vitale, Sarita Herse, Mary-Anne Williams, Xun Wang and William Judge; published in the Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction [384]*

7.1 UX Design for HRI

In this chapter, I present the next stage of the research, that described in Action Design Research as Building, Intervention and Evaluation (BIE), with this first design study. In the previous chapters, the research opportunity and contributing theoretical bases for designing social robot applications for public spaces, or lack thereof were identified. It was discovered there was a dearth, of beyond-theoretical knowledge, for creating social robot applications that 1) meet privacy legislation, 2) foster positive user experiences and 3) provide a valid proposition or use case for implementation by an organisation. Therefore, in this chapter, the conceptualisation of the problem space and the proposed Lean UX design process for social robots that enables addressing these three areas simultaneously, is presented.

For this first design study, the Commonwealth Bank of Australia (CBA) Innovation Lab partnership is continued and a project with their client, an international airline provider, is undertaken to explore how a social robot could be deployed at the airport to assist customers and enhance the customer experience. To platform the work, a comprehensive process that incorporated everyday business practice and expectations, plus evolving of design principles for social robot applications was required. In this process, work was closely undertaken with the partner organisation and client in mutually influencing roles, allowing continuous and re-occurring evaluation of both the process and the applications to be deployed. In doing so, spontaneous evaluations and iterative generation provided authentic and practical refinements. The end result is a comprehensive methodology for socially responsible and feasible social robot application design, development and deployment for commercial humanoid robots.

7.1.1 Beginning Design Assumptions

Several assumptions were made by the team and partner client in the carrying out of this study. These assumptions combined both the practitioners' and researchers' identified requirements for social robot application design, see Chapter 6, 6.1.1, and the client's additional expectations for the project. Assumptions were mutually shaped and articulated, as the team's understanding of the client's application domain increased. Additionally, specific client expectations regarding the final, proposed applications were named early. This ensured the best possible outcome for all stakeholders and especially for the intended customers, who would be using the experimental applications. The assumptions enabled and formed the basis for the fledgling design processes on which

the subsequent methodology is based.

The list from Chapter 6, 6.1.1, is repeated here with the additional assumptions in italics.

1. Any social robot application is designed and developed to function in a commercial manner for deployment, using today's technology and capabilities. This means no Wizard-of-Oz techniques, no robot operator controlling and assisting interactions.
2. *The application must be stand-alone and able to be used again and again by end-users without intervention by a practitioner or researcher, to reset or restart the application interaction.*
3. The application must be able to be used without human guidance. It has to be designed in such a way that end users can intuitively, or with guidance from the robot, make sense of how to use the application.
4. Any sensing or processing must be done as much as possible on-board the robot without the use of auxiliary equipment that would not be present in a real world deployment of the technology.
5. Any Artificial Intelligence systems used must provide a sufficient confidence and accuracy to be able to sensibly guide any decision making required by the robot or by users.
6. Repeatable and consistent functioning is expected at all times that the robot is deployed for use with end-users. There should not be any bugs in the software. Any unexpected malfunctions or lack of capability by the robot will be managed in a graceful fallback or degradation manner.
7. *Any visual design will be professional and in a manner that is suitably representative of the company. This also includes branding of the robot and tablet screen with the client's logo and identity.*
8. *The robot will be designed to behave in a manner that is respectful and polite, as would be expected for any customer-facing employee of the client. This includes gestures, language (inclusive and positive vocabulary) and tone.*
9. All functionality will meet privacy legislation requirements. *Complicated personal data management practices in the application will be avoided due to the time-limited nature of the study.*

10. The value the prototype application is intended to provide to customers is real, based on genuine need. There should be a real world benefit to the task the robot is performing.

11. *The application task must be able to be articulated and understood in any media regarding the robot and essentially, for any security regarding the robot and air travel management.*

The combined partnership and client team were able to successfully work together to actively trial a real world social robot applications at an international airport. In doing so, this advanced the methodology for social robot application design. In the following section is described the published process used in the real world study undertaken during August 2017 at Sydney International Airport. This is provided almost as-is from the publication, with additional detail added. It must be noted that due to the commercial sensitivity of the airport trials, disclosure of specific outcomes was not allowed. Instead, the outline of the social robot applications design process is given, in conjunction with the reasoning for each decision, being the area of most interest to this research.

7.2 Combining HRI research and UX Design

A social robot can be valuable technology to explore with, particularly within complex, human-centred environments. Airports can often be overwhelming due to the high volume of screens, signs, announcements, and people within a relatively small space. As such, airports are considered a breeding ground for confusion, stress, and anxiety [304]. In this situation, a social robot may be uniquely positioned to assist in ways that other technologies cannot. They may elicit social and emotional responses [322], and people may anthropomorphize the robot [136]. This may assist with bringing information to life, for people to understand in a short time-frame, vital in a dynamic, cognitively-demanding environment.

Bringing into this environment a new technology for use, such as a social robot, has to be managed carefully so as not to create a situation where people feel negatively impacted. The ideal situation is that a social robot positively enhances the in-airport experience for people. Indeed, the importance of creating positive user experiences with social robots has been raised in previous Human-Robot Interaction (HRI) research [6, 409]. However, a positive user experience (UX) has to be systematically and purposefully designed [6, 162]. How to design the UX of interacting with social robots so that they provide a positive

experience is an area that has been identified as being of benefit to the HRI field. It is a challenge waiting to be addressed [244].

It is not just airports that require this purposeful UX design. Any public space or public environments, such as a hospital, train station or office, where there may be a societal impact from a social robot, would benefit from purposeful UX design [409]. Furthermore, it has been suggested that positive user experiences are required to enable the increase of robot numbers in society [409].

To encourage the expansion of social robots present in society, potential commercial applications are required that can be taken up by industry. The real world application of social robots is an aspiration in the HRI field [25], and allows research regarding HRI to advance. It has also been suggested that to assist the long term acceptance of a robot, it should have a purpose for being there [166]. Furthermore, usefulness has been identified as a factor essential to social robot adoption [96]. Therefore exploration of the viable applications of social robots that meet a need in a specific environment is required.

This design study advances a practical methodology for firstly identifying viable, and potentially commercial, applications for a humanoid social robot in a specific environment, focusing on users' needs, and then comprehensively designing the user experience for the application and environment. It is proposed that two current issues in HRI, *1) the issue of identifying viable applications for social robots* and *2) the issue of how to create a positive user experience* are intrinsically related and should be addressed in conjunction. This holistic approach is in line with the thinking by Alben, that quality experiences come about "*when the design of a product is undertaken and developed as a whole*" [5, p. 14]. Addressing these two issues, together within an iterative design process, enables a greater chance of creating a long term, robotic solution that makes peoples' lives better and provides a business benefit.

As described in the introduction chapter, the purpose of this project is not limited to present the results of specific field studies for a particular robotic platform. Instead, this project aims to provide a detailed methodology suitable for the design of *social robot applications* for any style of commercially available *social humanoid robot* to be implemented in a public space. The described methodology 1) identifies commercial robotics applications addressing real users' needs for the considered context; 2) maintains the focus on designing an optimal user experience; and 3) easily integrates with the majority of design and development processes widely used in today's organisations regarding customer experience. UX is a component of customer experience, and *"must always be seen in the bigger context of customer experience"* [182]. There are limited

studies detailing user experience design which have been adapted for use in HRI [6, 244] and this project seeks to address this gap.

Additionally, the proposed methodology allows an iterative design life-cycle with continuous user feedback. This is a critical feature for designing practical robotic applications. It is suggested that this is a crucial first step for experiments in public spaces before any evidence-based evaluation is performed.

In the next section, details regarding how the Lean UX process is adapted to make it specific for use in HRI, based on the HRI literature and practice in the field, are provided. This is followed by a brief discussion of the limitations of the methodology and conclusions for the next design study.

7.2.1 User Experience for HRI

User experience can be defined as *"the totality of the effect or effects felt by a user as a result of interaction with, and the usage context of, a system, device, or product, including the influence of usability, usefulness, and emotional impact during interaction and savoring memory after interaction"* [162, p. 5]. UX is about the users' internal feelings that arise and hence is subjective.

Lindblom and Andreasson suggest it may be possible to positively influence the UX via understanding the user and the usage context, and designing the interaction with these in mind [244].

The importance of the situated context in UX is referred to by Hassenzahl and Tractinsky [164] and likewise situational context has also been identified as important in HRI research [6, 21, 329, 331]. Šabanović *et al.* describes the need in HRI research to *"address the emergent situated interaction dynamics between people and robots in specific contexts of use"* [331, p. 71]. Furthermore, the social context in which a social robot will function has also been identified as of critical importance [229]. A description of UX relevant for HRI by Alenljung *et al.* [6, p. 1]: based on both Hassenzahl and Tractinsky [164] and Hartson and Pyla [162], describes it as: *"an outcome of the interaction that depends on the internal state of the user, the quality and attributes of the product, and the particular situation"*

To summarise this understanding of UX for HRI I have adapted and visualised Alenljung *et al.*'s [6] and Hassenzahl and Tractinsky's [164] descriptions, supported also

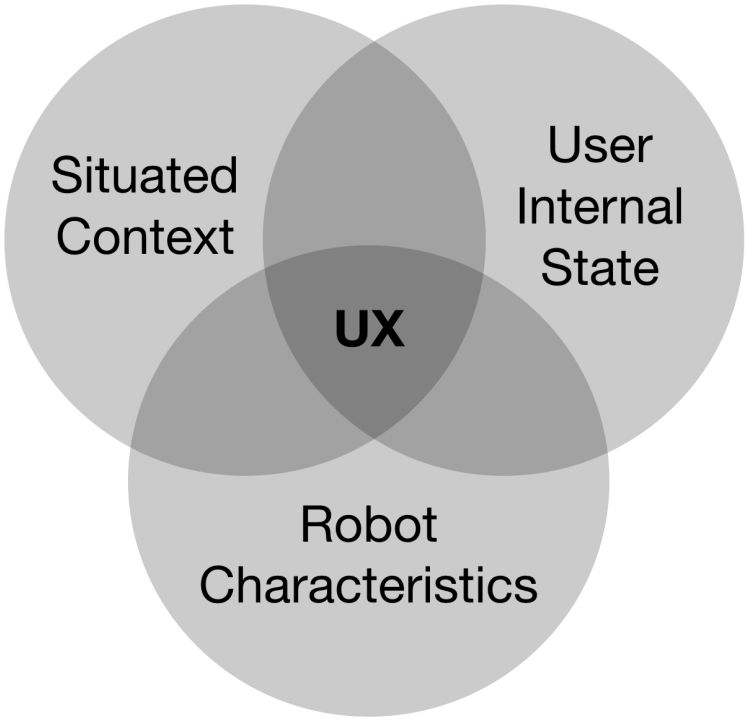


Figure 7.1: Visualising the focus for UX in an HRI setting, adapted from Hassenzahl and Tractinsky [164] and Alenljung *et al.* [6]

by the ISO definition of UX [1], and Šabanović *et al.*'s [331] HRI description, in Figure 7.1. This is explained as follows:

Situated Context The specific environment the robot is active in, combined with the social, cultural and business context.

User Internal State The users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments resulting from prior experiences, attitudes, mood, skills and personality.

Robot Characteristics The attributes and qualities of the robot, how the robot looks, moves, sounds, acts, behaves and interacts.

Positive user experiences are regarded as critical to the widespread adoption and use of social robots [409]. Consideration of the UX is essential in HRI, as a negative user

[1] ISO Standard for UX https://www.iso.org/obp/ui/##iso:std:iso:9241:-210:ed-1:v1:en:sec:2.15

experience may prevent users from further interaction and acceptance of the robot [94]. Hence designing for a positive user experience is vital. Understanding UX in the context of HRI allows us to now focus on how to design the UX for HRI. This is described in the following section.

7.2.2 User Experience Design

In recent years the shift in UX Design has been towards Lean UX practices, acknowledging the need for streamlining the process. Reducing the amount of documentation produced by the traditional UX process, reliance on one UX designer and the rise of "Start-Up" culture have also been key factors. Two practices are put forward for designing the UX of HRI. The practices of 1) Lean UX and 2) Agile Science [170]. Lean UX is suggested to be used as a basis to create a UX design methodology for HRI that both assists in creating viable applications and enhancing user experience. In addition, the suggested UX design methodology can be used as an important first step for experiment planning, as per Agile Science philosophy.

Lean UX is the combination of Design Thinking, Lean Start-up and Agile methodologies [151]. Lean UX is faster and cheaper than traditional UX design as it does not require the creation of detailed documents or long user studies. Instead, Lean UX's philosophy is the rapid building of Minimum Viable Product (MVP) prototypes that are iteratively built, released and tested with representative users. Hypotheses are used to test and ideally validate solutions. MVPs are the smallest prototype you can create to learn if your hypothesis is valid. Lean UX uses continuous feedback from users to guide the design process. Lean UX is a two stage process that has Design thinking as the first phase. Design Thinking is a non-linear design process for solving problems [48, 302, 386] and assists in finding solutions for the pain points of users based on the way they think, feel and behave. The five stages of Design Thinking, according to the Hasso Plattner Institute of Design at Stanford University (d.school) [2], are as follows: Empathise, Define (the problem), Ideate, Prototype, and Test.

These five main elements are described by the Interaction Design Foundation as tackling complex problems by:

" *(i) Empathise: Understanding the pain points of humans.*
(ii) Defining: Re-framing and defining the problem in human-centric ways.
(iii) Ideating: Brainstorming.

[2] https://dschool.stanford.edu/

(iv) Prototyping: Quick low fidelity prototypes.
(v) Testing: Developing a prototype/solution to the problem." [180]

The second phase of Lean UX is composed of two practices: Lean Start-up & Agile Methodology. Lean Start-up incorporates defining hypotheses for testing with rapid prototyping and iteration [316]. Agile methodology is a fast iterative method for time-boxed software development [1].

What is needed to be stressed here is that the quantified results from the hypothesis testing of Lean Startup *do not necessarily provide statistically significant results*. Instead, they are used to assess the feasibility of the application prototype *from a commercial standpoint based on a set of criteria defined during the design process*. The process may be repeated until a feasible application is confirmed. It is possible to then conduct an experiment in a more classical manner to investigate social and psychological effects of the proposed application and it is during this stage that Agile Science methodology can assist.

This Lean-Start-up stage is similar to the Agile Science process, described in the following section, which *"explicitly places questions of feasibility and construct specification as equally important to effect size estimation"* [170, p. 9].

Agile Science emphasises rapid, iterative development of a product within a highly specific context. It includes the cycling of two phases, a generation phase and an evaluation phase. The generation phase focuses on the development of operational definitions and constructs, which are assessed for feasibility using Lean Start-up methods [170] and concludes with the development of a MVP. These methods provide strategies for identifying assumptions about the product and identifying the most 'lean' (i.e. resource-efficient) strategy possible for testing those assumptions.

During the evaluation phase, the MVP is presented to relevant populations and/or stakeholders and the previously defined assumptions are assessed. Effect size estimates, causal inferences, and general feedback can then be fed back into the generation phase for the next iteration.

While planning is the crux of experimental design, Agile Science allows for much-needed flexibility and agility in order to accommodate changing requirements in highly volatile, contextually specific environments.

It should be noted that Agile Science methodology does not have an ideation phase; the product concept is already established. It is in this perspective that the first stage of Lean UX enhances the proposed process.

7.2.3 Incorporating HRI research into UX Design

The Lean UX process is proposed to be used in this research as a basis to design a positive user experience for HRI systematically. In addition, incorporating the philosophy of Agile Science into the process's Lean Start-up stage allows for standard quantitative research methods, including tests for statistical significance, to then be performed as a final step. This study provides the example of a first iteration of the Lean UX process, that is, testing the feasibility of the proposed applications from a commercial standpoint.

Moreover, making the methodology novel and specific for HRI, learnings from the field of HRI are incorporated. This is realised by including a *Personality design* and *Interaction design* stage. Additionally, the process for these is based on the ideas of co-design, which can be thought of as an extension of participatory design [335]. The idea is to attempt to involve all participants in the design process. Value has been found in the participatory design process in other HRI studies [18, 229, 321]. For example, participatory design has been used to identify social structures and contextually meaningful robot applications in studies with older adults suffering depression[229].

The underlying basis for all of the above processes is the need for iterative design based on continuous user feedback. The idea of iterative design is nothing new: Nielsen demonstrated the benefit for iterative interface design in 1993 [282]. Iterative design has also been described and used in HRI studies previously [232, 330, 331]. In fact, iterative design was found to be a critical feature for designing feasible robotic applications in the studies. The Lean Startup field also identifies iterative design based on user feedback as crucial to success [151, 316]. As such, the iterative design process is highlighted as critical to the UX-HRI methodology.

The UX-HRI methodology provides creation of feasible robot applications for commercially available social robots that address pain points of users in specific environments. Additionally, by basing the processes on Lean UX, it actively designs for the user experience. In the methodology, the application and UX design are actively intertwined. In the next section, the detail regarding the proposed methodology for designing the UX for HRI is provided within the context of the airport study.

7.3 The UX-HRI Design Methodology

In this section the processes for designing a comprehensive user experience for a social robot application, inspired by the theory and methodology outlined in the previous sections, are described.

This methodology may assist in both designing and testing social robot applications that address real needs of users and assists in developing a holistic, comprehensively designed, user experience.

All of the steps were performed by the research team, composed of academics and design practitioners from the CBA Innovation lab, and the international airline client employees. The research team possessed a variety of skills and capabilities, and collaborated together as required at different times. It is suggested the whole team—designers, developers, researchers and all other team members—go on the field research together, to ensure all share a common understanding. This is in accordance with Lean UX philosophy [151]. The methodology is presented here linearly, as per the design study trial, but it is not required to be that way. What the methodology does allow is a high-level view of the different components that enable a comprehensive user experience to be created and trialled. Different components may be picked out and selected for use, and may also be applied to situations where a robot is already in situ.

It should be noted that this HRI-adapted Lean UX design methodology is specifically for commercially available, social robots. In light of this, a pre-step to the methodology may be the selection/purchasing of the robotic platform to be used. This may be dependant on availability and affordability, political or environmental considerations. In some cases, there may be no choice in the purchase for the researchers or the design team. A vital consideration must be given to the social robot chosen, as the appearance and affordances of the robot, including its possible range of dynamic motion, has significant impact on user interaction expectations and subsequent experience [177].

The social robot for the design study, is again the PAL REEM humanoid service robot[3] as used in the previous chapters. The robot is wheel-based, 1.7m tall and has a pair of 4-degrees of freedom (DOF) arms and 7-DOF hands, allowing it to gesture in a human-like fashion (Figure 7.2). The height and the ability to gesture were significant as the robot would be required to be able to attract attention in a noisy airport environment. The ability to use non-verbal, human-like gestures may also assist in the intuitiveness of the interaction [31], reducing the amount of cognition required by users to understand the robot, which was considered as necessary in what may be a stressful situation for some users. The robot incorporated a touch screen on its chest, allowing the display of images and text that complemented the robots' speech and gestures, also importantly providing a utility for an accessibility option for the hearing impaired. In addition it allowed for branding to be displayed.

[3] http://pal-robotics.com/wp-content/uploads/2016/03/REEM-Datasheet.pdf



Figure 7.2: The robot used in the study.

7.3.1 Define the Challenge

This step started with the situated context and the question: *What is the specific environment the robot will feasibly be interacting in?* This is used to describe then the overarching issue to be addressed. For example, in the study, the environment was the airport, and the specific areas accessible for the robot were the Check-In counters, Premium Lounge and Gate. Hence the statement was defined as the following *"How might we use social robots to enhance the in-airport customer experience in the Check-In, Lounge or Gate environments?"* Another, hypothetical, example of an environment may be a hospital and the statement may include a specific user group *"How might we use social robots to improve the experience for patients in the surgery prep room, overnight ward or visitors room environments?"*
Outcome: 1. Situated How-Might-We statement.

7.3.2 Observe

Secondly, the environment was visited with the team at different hours of the day at the specific locations as part of a "needfinding" exercise [299]. This allows team members to experience the environment and empathise with customers, listening to their feedback and observing, and immersing in the status quo. It allows an understanding of the social context and an awareness of the social facilitation effects [420] that may be at play in the environment.

The visits were timed with departing flights, allowing the team to experience the customer journey from check-in, lounge, to gate. By collecting information from within the context of the entire experience, rich information could be gained. Team members paired up and took turns, either taking notes or interviewing and observing the people present in those locations.

Interview questions that were asked of the people present included:
"How did you feel when you arrived at the location and why?"
"How does the current experience at the location make you feel and why?"
"What's the worst part of being in the location and why?"
"What's the best part, or a previous good experience, you've had at that location and why?"
"If you could change anything about the experience at that location, what would it be and why?".

Every person present in the location is considered relevant to the experience of being there; however, the interview questions differ slightly. For example, when a staff member

was interviewed the questions would change to *"How do you think customers feel when they arrive at that location and why?"*, *"What's a previous good experience you've had helping a customer and why?"*. Staff members at the locations were especially relevant as they have the most knowledge from their day-to-day interactions with customers, accumulated over time. Only speaking to the intended, direct users of the robot may miss the insights that can be gained from others who are regularly present in the environment where the robot is intended to be located.
Outcome: 1. Team members with an awareness and experience of the environment and understanding of the social context of the environment; 2. Observations and feedback notes.

7.3.3 Form Insights

Once back at the lab, each team member read out their notes taken and each item was written on a Post-it note and placed in the relevant quadrant on an Empathy Map [294]. "Think aloud" synthesising of the information also occurred. The Empathy map contains the 4 quadrants: Say, Think, Do and Feel. Insights into opportunities and pain-points, especially from surprising tensions, and the overarching emotion/s at the location were noted. Next, the end-to-end (e2e) customer journey at the specific location was mapped according to Activity, Emotion and Insight. An example customer journey appears in Figure 7.3.
Outcome: 1. Empathy Map with Insights into pain points and opportunities; 2. End-to-end customer journey for each location.

7.3.4 Frame Opportunities

From the insights into pain-points and the e2e journey, specific How-Might-We (HMW) statements were created. For example, in the airport example, it was discovered that customers feel simultaneously anxious and bored when waiting in the gate area. Hence one HMW statement was *"How might we make time seem to go faster when waiting in the gate environment."*.
Outcome: 1. How-Might-We statements for each location.

7.3.5 Brainstorm

In the Brainstorm ideas phase, the How-Might-We statements were used that were generated from the customer pain-points and insights as platforms for idea generation.

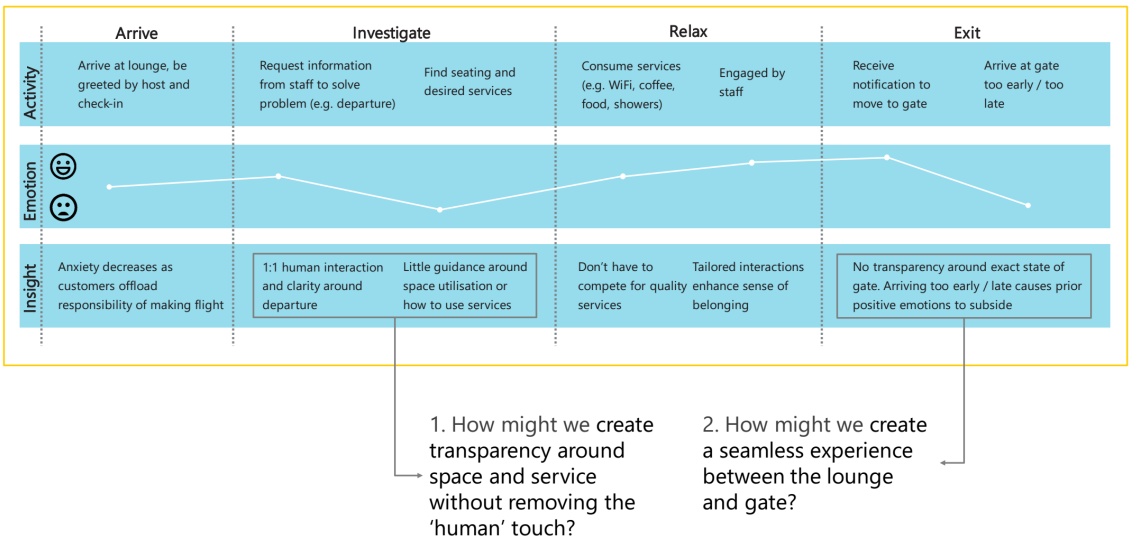


Figure 7.3: Example customer journey in the Lounge

Adapting standard design thinking, a constraint was added to the beginning of the HMW statements — "How might we *use a social robot to*". A combination of brain-writing/brainstorming was used, where ideas that will solve/address the HMW statement are silently written down on Post-its by team members, then voiced, built on and blended, without judgement [294, 386].

Over 250 ideas were generated as to how a social robot could enhance the check-in, lounge and gate environments. These were then grouped into concept themes, voted on by the team, and the most promising 10 concepts brought to life through storyboards. The concept ideas were filtered via *feasibility, viability, ethical and commercial value* but other criteria can be used depending on the considered context.

Importantly, the possible privacy impacts and risks were evaluated, as this becomes particularly relevant when designing the UX of robotic applications [328]. It was decided to avoid any applications that involved user identity or collection of personal details by the robot. This was due to the technical difficulty of meeting privacy legislation for customers to be able to change or update data.

The ideas were mapped on a high/low quadrant of Ease of Implementation vs Impact. Two final concepts were chosen and a full end to end storyboard created. A name for the role played by the robot in the storyboard was chosen. For example, at the gate, the name chosen for the role the robot could perform there was "The Gate Guru".
Outcome: 1. Concept applications with full end-to-end storyboard.

7.3.6 Design Experiments

Next, hypotheses were articulated for testing the viability of the two final concept applications from the Brainstorm step. The measures and criteria for success of the hypothesises were established. These criteria were based on both the standard practice of the commercial partner and theory from the HRI field, which included factors from the USUS framework [408]. The USUS framework provides guidance for evaluating usability and UX, and assists in determining which methods are appropriate to use for single aspects of HRI.

For example, the leading hypothesis for the check-in environment was *"Customers will have a more enjoyable check-in experience, with the robot present, then currently"*. Agreed measurements to test this hypothesis were via direct customer feedback, with customers rating their experience on a 7 point scale, after the check in process was complete, on flight check-ins with, and without, the robot present. Additional testing included sub-hypotheses such as *"Customers will engage with the robot and interact in a social manner"*. Measures included observation, counts of the number of people approaching and interacting with the robot and counts of people then agreeing to hear a joke from the robot. An example criteria determined for success for this was: *">50% of customers who are engaged by the robot interact and request a joke"*. For some sub-hypotheses there may be no initial criteria for success as the measure itself is a trial.

Defining the hypotheses meant a list outlining the MVP could be created and used to create a prototype of the concept applications from the Brainstorm, to validate the hypothesis. An adaption was made to the process here, as the robot may be considered by users to be a social actor [95] and the robot is actually performing a role in the environment much as a social actor does. Hence it is suggested that it could also be referred to as the Minimum Viable Role (MVR) that is created for the robot. In the airport field study, the MVP list for the robot at the check-in sounds very similar to a role description, and included the following:

1. The robot welcomes customers as they approach the check-in area

2. The robot introduces the process to customers and gestures towards the self-service kiosks

A point it is essential to understand here is that the standard experiment process in HRI generally relies on reporting significant effects via p-values [25], which may be suitable for controlled experiment environments. However this is not what is required

initially in this commercial setting. The iterative process provides quick turnarounds and rapid feedback to help direct design. Descriptive statistics can provide guides as to what is working and what is not, and these are used to then re-formulate new hypotheses for the next round of testing. For some sub-hypotheses there may be no initial criteria for success as the measure itself is a trial.
Outcome: 1. Hypotheses, Sub-Hypotheses, Measures and Test Success Criteria; 2. Minimum Viable Product/Role outline.

7.3.7 Design Personality and Identity Principles

Once the concept application was established, the iterative development of a prototype application starts. This is carried out in conjunction with continuous user feedback. The process of designing the robot personality and identity principles began with establishing a foundation personality for the robot that is representative and in-line with the airline company branding and values and the role the robot is going to perform.

The design entails an iterative process involving paper prototyping, role play, and soliciting user feedback. The location of the development and the one of the study gave an advantage to gather users' feedback. The innovation lab where the development took place has a steady stream of visitors able to provide instant feedback on role-played prototypes and interactions. Similarly, the airport environment is one that has been experienced by a large proportion of the everyday population, thus giving access to much important feedback from representative users.

Personality has been identified in the literature as essential for social robots [231] and hence is considered an element contributing to the success of a robot in public spaces. It has been found users may automatically attribute a personality for the robot themselves [95, 402] and personality attribution may be difficult to avoid and is in fact advisable to expect [281]. Indeed, as the user experience is being systematically designed for the robot, the design of the personality must also be in-line with the intended experience. This is especially important in this design study working with an airline, where brand values are an essential consideration in all parts of customer experience design.

Using the categories Who, What and How, the personality principles for the robot were forged.

Firstly, the MVP outline and the end-to-end storyboard were used to complete the role description for the robot. Under the heading "What", what the robot should do was listed out with the expectations for the robot in the specific role, much like a job description. For example: "Work alongside, in collaboration, not competition, with human staff".

Then, using the role description and the airlines' values and branding guidelines, personality features were described that would be suitable for the role description. For example, in the design study, identified were the descriptors: Friendly, Helpful, Jovial, Fallible. This was the "Who" stage.

Thirdly, a description of how the robot should interact, based on HRI literature and combined with its personality and role description, is outlined for the "How". HRI literature outlines the importance of enjoyment and sociability in interactions with social robots [94], setting expectations [220, 295], and creating a sense that it is different to humans. Welge and Hassenzahl claim that, *"the design challenge is to create a hybrid that invites people to emotionally interact (through having traits of 'beings'), but at the same time clearly communicates its 'being different'."*[410, p. 995]

For example in the airport study, the robot was to interact in the following manner. "Give people a reason to smile", "Ensure everyone knows it is imperfect" and "Create a sense that it is different to humans, in an amusing and humble way".

Also decided in this stage is the identity design for the robot. This is similar to corporate identity design and branding—applying logos, colours and other visual elements. Identity has been described as communicating the values of a product, due in part to how it looks and the associations it invokes [218]. In this process identity design is also based on the idea of surface credibility, that people form *"an initial judgement about credibility based on first impressions of surface traits, from a person's looks to his or her dress"* [124, p. 132], and that people will perceive the robots communications as credible when they can identify it as associated with a credible source (in this case, the airline) [111].

In addition, the identity design aims to provide consistency of appearance with the robot's role, as a representative of the airline, and behaviour, inline with that suggested by Walters and colleagues [402]. In the design study this meant the robot wore a badge that identified it as a 'Trainee' for the airline, and the logo of the airline appeared on the screen at all times. The trainee badge was displayed to indicate to customers that the robot may not be completely proficient in its role. Hence their expectations would be lowered.

Furthermore, the identity design allowed the creation of consistent marketing material for the release of the robot in the airport. This comprised short video segments, online news and magazine articles and media releases [4]. The marketing material assisted in setting customer expectations of the robot. Setting user expectations in this

[4]https://www.businesstraveller.com/business-travel/2017/08/22/air-new-zealand-experiments-robots-sydney-airport/

way goes toward preventing an 'expectations gap' [220] and shapes user beliefs about the capabilities of the robot [295].
Outcome: 1. Personality Principles - Who, What, How; 2. Identity Design - The visual styling of the robot. 3. Marketing materials to set user expectations

7.3.8 Design Interaction Behaviour

The Interaction design stage may be thought of as the most complicated. It comprises creating the behaviour flows for the end-to-end journey of the user in the environment. This entails the necessary movements, speech and multimedia that the robot will be employing. In addition it provides the position and mapping schematic of where the robot may travel in the environment. As with the Personality design stage, it involves continuous user feedback, and utilises sketching, paper prototyping, mapping and role play. See Sirkin *et al.* on a excellent list of references to assist [359].

It should be noted that this stage is not limited to a tightly scripted interaction, though if that is required it will work too. What it does provide are guidelines for the interaction behaviour, that can be used for development. For example, if the robot has specific phrases it should use for fulfilling its role, those are articulated. However, it might be that the speech of the robot will be provided dynamically, from the cloud or environment specific sources, or the conversation with the user, or the physical location of the robot in the environment. Business rules, such as recognising and greeting returning customers, may be included in the speech behaviour.

All of the interactions are based on the situational context, the robot's form and personality and the storyboards that outline the concept that fulfils the How Might We (HMW) statement. The robots form and movement is an important consideration here, as it provides context for the interaction affordances [177]. The interactions may be developed with actual users, informing the design, using methods such as participatory design or co-design. In fact, co-design has been described as an ideal companion to Lean UX, albeit with children as the participants [104].

In the design study, a typical outcome of this stage was a behaviour flow at specific locations within the environment of interest. By co-designing with the airline staff, specific locations were easily able to be identified as being of the most appropriate for an interaction. For example, within a gate area, there would be a position where the robot could stand and address the seated customers, waiting to board their plane, without getting in the way of airline staff. In the behaviour flow for this specific location, one of

the topics the robot may provide information about was the weather at the destination city. An example is provided in Table 7.1.

Table 7.1: Example of a designed robot behaviour at the Gate

Behaviour	**Destination Information (*Example only*)**
Screen	The four day weather forecast for the destination city. Randomly rotating images of the destination city at different times of day.
Motion	Points to sky to indicate weather, General talking movements when describing location. Moving along predefined path p1 or p2, stopping at predefined points in a random fashion.
Speech	[if raining] Hope you packed an umbrella, it's raining and [18] degrees in [destination] today. Too wet, for robots.

The screen itself also involved a mini iterative, interface design process, for each behaviour. The different screen interfaces that would be displayed during the speech were also interactive and able to be delved into by customers using the touch screen. In this area for the design study, the airline specified web and TV screen style guidelines and interface examples that could be customised for use on the robots touch screen. Considerations to account for included the sizing of graphics to make them appropriate for viewing at a distance and up close.

The position and mapping schematic also provided detail as to which areas could be used autonomously by the robot and which areas were deemed too risky. An example diagram from the design study that demonstrates the robot's allowed navigation (P1, P2) and static positioning (P3) for the Gate can be seen in Figure 7.4.

Outcome: 1. Position and Mapping Schematic; 2. Behaviour Flow for each specific location/activity detailing the speech, motions and screen expectations for the behaviour.

7.3.9 Prototype and Build

Again this stage involved continuous iteration and testing with users. In the design study the building of the prototype behaviours was actually running concurrently with the interaction design stage. The reason this stage is pulled out of the personality and interaction design stages is to highlight the impacts technology can have on a robot application. In addition, some teams may be smaller in size and only able to progress one stage at a time. The interaction design of the robot is underpinned by technological

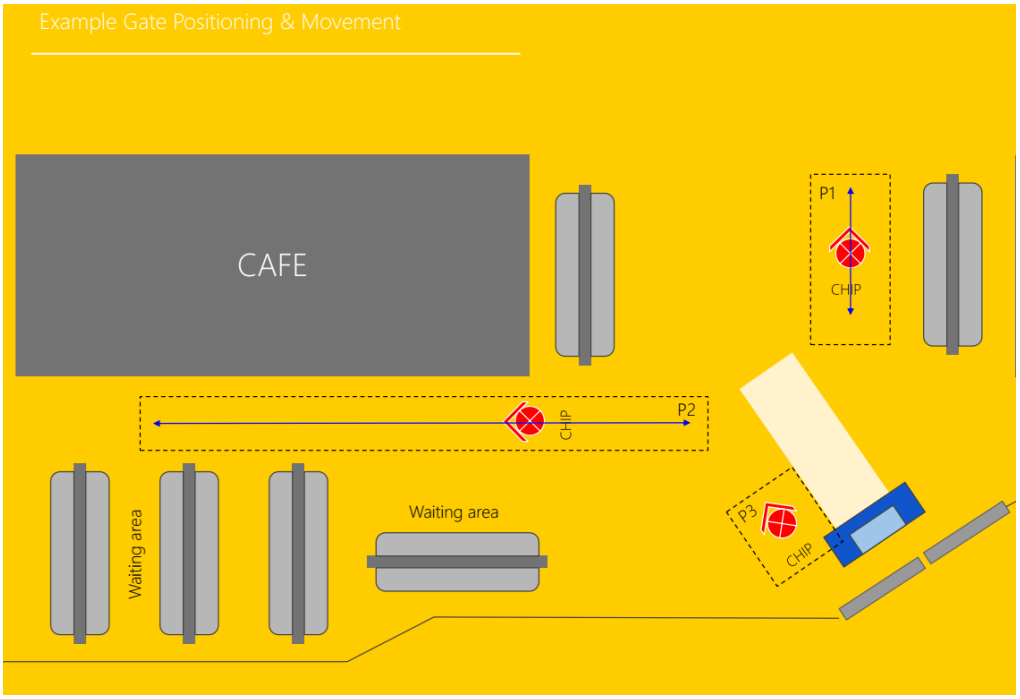


Figure 7.4: Example positioning and schematic diagram

aspects such as text to speech, speech recognition, robotic localisation and mapping, and computer vision. In some cases, what was thought possible with the technology was too slow or error-prone when tested in a prototype build. Due to the iterative, continuous testing nature of the process, this would be discovered almost immediately, and the interaction changed appropriately. This prevented taking a robot to the field that would be off-putting for users, due to seeming unresponsiveness of the robot. It also allows for technologies to change and progress. For example, a different method of scanning the boarding passes by the robot was able to be identified in the lab during testing, this behaviour was then put back into the interaction design process. The high-level summary guide presented in Figure 7.5, highlights the repetitive nature of this stage and the novel, HRI specific design stages. It is suggested that there is no strict rule for the iteration process or creation of massive documentation, other than the outcomes from the previous steps, in this stage. As all team members have different perspectives yet share a specific agenda to work towards, a fluid style of working together allows for quick prototyping and development.

Outcome: 1. Minimum viable product prototypes for testing with users.

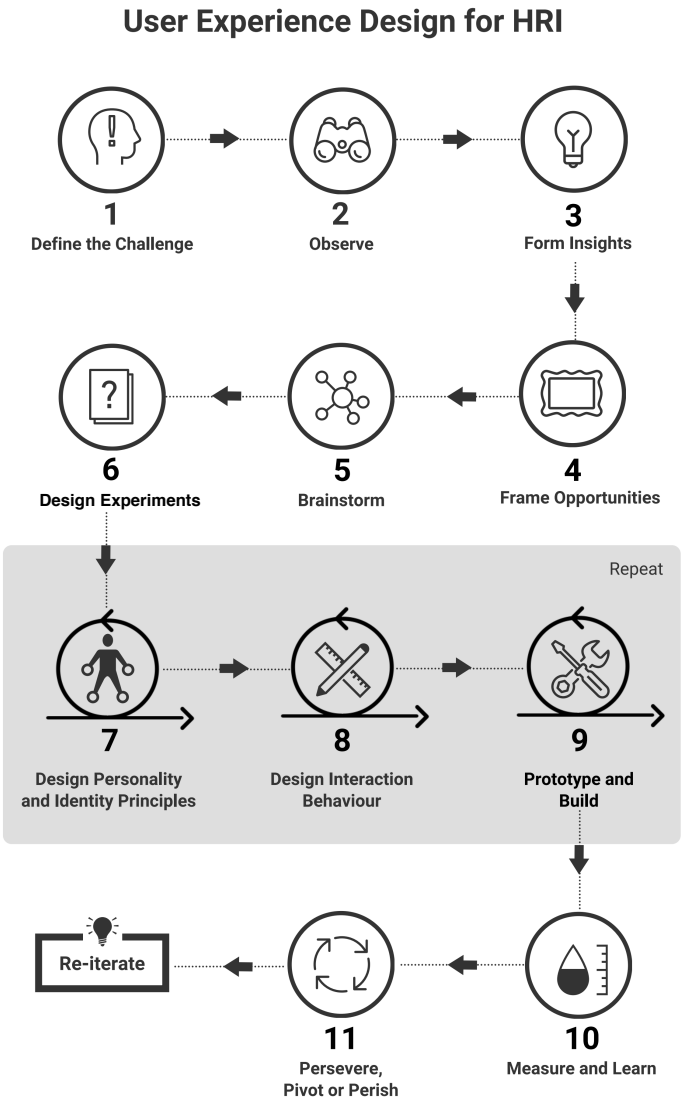


Figure 7.5: The UX-HRI methodology. HRI specific, novel contributions, Steps 7 and 8

7.3.10 Measure and Learn

In this phase the robot is deployed with its new capabilities to the environment. The hypotheses are tested using the measures and success criteria defined in the 'Design Experiments' stage. For this design study, the USUS evaluation framework [408] was, where possible, employed for use.

The robot was trialled for one week in the airport check-in and gate environments for the first iteration of in-field experiments. The evaluation was limited to customer observation, interaction counts and feedback questionnaires, both in part to the framework and to the commercial partner requirements. Four team members were actively

observing responses to the robot and taking notes along several pre-defined categories, including reactions and emotions, instances of touching and interacting with the robot, and entertainment and technical aspects. Additionally, people's comments were noted. Customer feedback questionnaires were conducted in both environments.

To provide a baseline, customer observation, counts and feedback questionnaires were also conducted for the same departing flight times in a different week, without the robot present.

Surprising and unexpected behaviour was noted. For example, counts of voice interactions were surprisingly low, and voice interactions occurred in unexpected ways or at unexpected times. This type of learning provides valuable insight for further iterations and possible applications.

Outcome: 1. Learnings from the experiments. 2. Validated/Invalidated hypotheses.

7.3.11 Persevere, Pivot or Perish

In this final stage the insights and implications from the experiments are reviewed and the next steps decided. This may be re-iterating from any stage, generally however from either Steps 4 *Frame Opportunities* or 6 *Design Experiments* upwards. There were unforeseen behavioural changes (a calming effect) as a result of the robot's presence. These require a second, more extended experimentation period, and larger data sets to be able to validate confidently. Additionally, there are a variety of learnings around navigation, speech recognition, and computer vision interaction design. Several concepts or features which were not tested due to time limitations may also be incorporated into a second iteration. The question is whether, or not, to tweak the current experiment based on insights and learnings discovered, for validated hypotheses, and hence *persevere* with the concept application. Alternatively, *pivot* the experiment to other areas, environments and applications, if hypotheses were perhaps only partially validated. For example, in the check-in environment, it was found that of the users who engaged and were aware of the robot, >50% of users interacted with it via touchscreen or voice to request a joke. However, actual voice interaction was very low. Therefore greater work is required to make the voice interaction more obvious and seamless, as customers tended to fall back to the touchscreen if voice appeared not to function effectively, and this could be tested in the next iteration.

Otherwise, when experiments were found to be invalidated, the behaviour and or concept application could be considered perished. For example, not one person accepted the robots offer to check their carry-on baggage size. Hence, rather than continue with

progressing behaviours or applications in this area, more significant benefit can be found instead, in enhancing the behaviours where people did interact and report an increase in enjoyment of their experience.
Outcome: 1. Next Steps - which behaviours and concept applications to progress, what to pivot towards or drop, and which stages of the methodology to revisit.

7.4 Discussion

The UX-HRI methodology outlines methods and processes for the design and development of commercially viable robotic applications, with practical designed user experience, for commercially available social robots. It uses an iterative process and draws inspiration from Lean UX, rapid prototyping methods and incorporates and synthesises many findings from HRI research and literature. This results in the development of a MVP, which may then be either assessed for commercial viability in the wild, used in evidence based studies within a lab, or taken by a commercial company, depending on how far along the design process has run.

This study provided the steps leading up to, and first iteration of, real life testing for a feasible commercial application, with a social robot in an airport. The MVP applications were situated in the check-in and gate environments of the airport and tested with a range of hypotheses regarding how the new experience would address the customer pain-points (identified in the first steps of the methodology). By collecting an array of data, observations and customer feedback, the hypotheses were validated or invalidated as appropriate, giving insight as to which aspects of the MVP merited persevering, where pivotal thinking was needed, and validating where commercial value may exist. By using the UX-HRI methodology it was ensured that the trial application avoided a negative impact on the customer experience at the airport, and in fact improved the experience. Customer feedback from the check-in environment found that the experience was made more enjoyable, for some customers, by the robot. As per the methodology, additional iterations and testing would be required to assess further and hone the value of this for commercial application.

The role and personality developed for the robot was considered as integral and at the end of the trial it was even reported by an employee that the robot was a part of the team now, and would be missed. The design study required involvement from the Airport and Airline, Management and Operations, CX, PR, Brand and Digital teams. It consisted of over 50 hours of field experimentation, 28 flights, around 3000 airline passengers and

collected over 200 pieces of customer feedback. The methodology and the collaboration it engendered, was regarded as highly successful on a number of levels, by all involved, demonstrating the methodology's effectiveness for working with industry.

It could be observed that people closely follow social norms for interaction, engaging and responding to the robot in a social manner. A somewhat surprising finding was the calming effect the robot appeared to have over customer behaviour, with fewer customers observed standing up and crowding while waiting for boarding, when the robot was present in the gate environment. This may be due to the increased communication and transparency provided by the robot regarding flight information. Further testing is required to understand this phenomenon and to ascertain if this is a sustaining or significant effect. The next step in the process for this would be along Agile Science philosophy, establishing effect size estimates and causal inferences.

It is widely accepted that investigation into HRI requires a multidisciplinary approach in order to allow significant advancement in the field [114, 231]. Throughout this process and related use case, it was demonstrated that the proposed UX-HRI methodology can **facilitate cohesion and the synthesis of ideas between varying disciplines throughout every stage of the design, implementation, and assessment process**. The proposed methodology encourages the whole team, *i.e.* designers, developers, researchers, industry partners and all other team members, to work together during all the phases of the methodology, ensuring all are on the same page. Ideas and inputs from all areas are taken into account, definitions agreed upon so to minimise confusion, and the specific purpose of the product is agreed upon. Further, all disciplines are involved in the implementation and evaluation of the product within the real-world setting, encouraging team engagement and efficiency in task completion. This promotion and emphasis of the inclusion of varying disciplines throughout each stage of the methodology honours the call for different perspectives and a much needed multidisciplinary approach within the field of HRI.

The UX-HRI methodology makes as a priority robotic applications that can be successfully integrated into public spaces by emphasising the importance of a comprehensive consideration of user pain points and feedback during the design stage of a MVP. Furthermore, the UX-HRI methodology provides a greater focus on considering a viable end product in the wild, that in turn allows further controlled environment research for HRI with a greater chance of external validity.

While the UX-HRI methodology offers many benefits to further developing the field of HRI, it is not without its own limitations. Namely, it is apparent that this style of design

has only been utilised for standard platform robots that are humanoid. However, the process may be able to be readily adapted to include the design of the robot body/hardware. The benefit of working with highly experienced individuals, from the industry partnership, streamlined the effectiveness of the methodology. Future studies involving different teams will confirm if the methodology works effectively across multiple domains and possibly different teams.

7.5 Reflections and Learnings

Years of research in HRI is now giving us the potential to employ robots for commercial applications. Although HRI literature provides crucial insights for the design of robotics applications, industry partnerships are demanding more profitable design methodologies that are able to develop viable commercial applications for robots through the integration of UX best practices.

This UX-HRI methodology, a Lean UX based methodology, is a way to fill this gap. This methodology was successfully employed for an experimental design study involving the trial implementation of a social robot at an airport. By bringing together 'Lean UX' with HRI research, it was possible to work with industry to design practical, real-world robotics applications and an effective, comprehensive user experience.

The design methodology included at least three advantages: 1) it combined the best of rapid prototyping and Lean UX practice with supported findings from HRI research literature 2) it supports today's organisations regarding customer experience and HRI's call for multidisciplinary collaborations and co-design; 3) it promotes human-centred design as a first step over classic evidence based methods for furthering HRI research.

As a first iteration project for the Building Iteration Evaluation phase of Action Design Research, *i.e.* discovering methodology and principles for social robot application design, this was a most valuable study. Following is a summary of what the design study achieved for the overall research project, what could have been improved or performed differently, and what is still remaining to be ascertained.

7.5.1 Application Considerations

The applications created and trialled at the airport were a direct result of the UX process. The HRI specific additions to the Lean UX process meant a social robot application

could be effectively created for study that met the latest in HRI research. Noted for the application design is the following:

1. Personality design: Providing a personality for the robot, as highlighted by the literature [95] to be vital for facilitating social HRI, appeared to play a role in people forming a social relationship with the robot and employees considering the robot as part of the team. The method of designing the robot's personality around the job description of the role the robot was undertaking and the company values, contributed to the personality that the robot displayed in conversation. Previous work in the area of robot personality design has described providing a back story for the robot, as a way of providing depth to the personality and engaging users [234]. However, we did not trial this method. An important value to companies is trust [333]. It was preferred by the team to instead to be honest and authentic in the robots communications, as it would be clearly fabrication to create a background story for the robot as per previous studies. The environmental context precluded any action that may impact on trust. This was also a consideration in the interactions with the robot, where it would acknowledge its failures or lack of ability.

2. Interaction design: The combined mapping out of the behaviour of the robot via speech, movement and tablet screen ensured a seamless integration of the functionalities. It also meant if a change was required, all areas were consequently considered for updating as well. Furthermore, the positioning schematic diagrams were vital for the managers of the public space to incorporate into their security considerations.

7.5.2 Process Considerations

The design study process was considered as very successful on a number of levels, by both practitioners and researchers. The following items deserve note regarding the overall process:

1. Multi-disciplinary team and organisational collaboration: The design study was a highly collaborative project that brought together researchers, practitioners, front-end employees, designers, developers, management and end users. The airline company supported this collaborative team with input and expertise from their Digital, CX and UX, Brand, and PR teams. What worked well with the different

expertise was the development of shared understanding via the initial discussing of assumptions, the needfinding and brainstorming exercises. Everyone's input was valid and added to the design.

2. Design Thinking: Very few studies could be found in which Design Thinking had been used, in social robotics and HRI research, before this study. Martini *et al.* 's and Eftring and Frennert's [110, 255] studies being the most relevant, yet neither describes involvement with a large organisation. The Design Thinking approach can be seen to be used in more recent studies [263, 392], presumably as knowledge of the methodology's effectiveness in design grows. The design thinking approach enabled potential applications to be prototyped and tested on location with a solid understanding of the user pain points they would be addressing. This is in direct contrast to more traditional projects where a robot application may be pre-made without initial input from potential users.

3. UX Process: The Lean UX process, with its 'less waste' philosophy of avoiding unnecessary documentation and work that is not used in the final product allowed a significant sized project to occur in an extremely short timeframe. The emphasis on every member of the team being involved in the needfinding process and visiting the considered locations ensured everyone knew how users thought, felt and behaved. The team members experienced the location, the constraints and pain points for people within the environment. This alleviated the need for time intensive deliverables, such as the production of detailed personas, a popular technique in regular UX practice [181], used to make the end user visible to development teams. Lean UX instead advocates for proto-personas, rough sketch personas based on hours in the field, not months of research studies. Furthermore, other popular deliverables for UX professionals such as detailed documentation defining UX goals for a product were not missed. Instead, the UX goals could be found as already articulated in the naming of assumptions, the forming of insights and framing of opportunities' stages. For example, the "How Might We" statement in effect gave the UX goal. The HMW statement *"How might we make time seem to go faster when waiting in the gate environment."* may essentially be distilled as an *"empathy"* UX goal [199]: "Make time seem to go faster for customers waiting in the gate environment." with the hypothesises and success measures for the prototype confirming if this goal had been met. Note: in a longer, less time-intensive project, personas would be helpful to create after the needfinding exercise. The personas

summarise key insights about end-users for team members who can not attend the needfinding on location.

4. Real world testing: Knowing an application was built to address a customer pain point specifically and with comprehensive UX design to facilitate it, enabled clear identification of when a user behaviour occurred that was unexpected or due to factors in the situated context. For example, a “checking of baggage size” application by the robot was developed to meet the need of users who were already in the queue for baggage drop off and wanted to test the size of their bag quickly. The application tested within the lab as being intuitive, quick and easy to use. However, the application was not used at all by customers when tested within the airport. It is suggested there may have been a perceived risk by users that prevented them from using the application. If the robot declared the bag was oversize, it might prevent the customer from taking it on board the aeroplane, or they might have to check-in the bag. If no one from the airline tests the bag size, this risk is lowered and they might ‘get away with it’. This real world risk did not arise in the testing of the prototype within the innovation lab. Without the testing of the prototype in the real world, this might have been considered a viable use case.

5. Setting Expectations: This design study confirmed the importance of the creation of marketing materials for the trial implementation as people reported they were expecting to see the robot assist them at the airport. Hence this suggests the design assumption regarding setting expectations through marketing was successfully enacted.

While the majority of iterations underwent constant evaluation and changes, there were still areas that could have benefited from changing.

1. On location development changes to feedback: Some interactions and behaviours simply did not translate as well to the airport environment from when in the lab. The ability to address these immediately on the fly would have improved the experience and allowed increased iterations to occur.

2. Staff feedback on site: The physical presence of the robot on location with the staff triggered a number of suggestions for the robot interactions and feedback. Again it would have been ideal to address these immediately.

3. Inclusive design: While this is a stated goal, the difficulties in developing for this limited the extent to which the application could be considered inclusive. For

example, re-directing users with un-catered accessibility needs to human assistance is a fallback that could be improved on.

For future deployments, a learning from the above items is to have an implementation session where the robot is onsite but not yet available for customer use. In the session, on site staff could run through the behaviours and expected interactions, provide feedback and changes appropriate to the situated context, and these changes could be made on the fly to the application, to be further evaluated immediately. In this way, areas could be improved without a time lag between iterations.

The design study explicitly incorporated privacy, UX design and HRI literature. However, due to the aim of the project to not include collection of personal data in the social robot applications, privacy management issues were negligible. Therefore in the next design study I further expand on the design methodology process and use Privacy-by-Design in an application that will collect sensitive data.

7.6 Next Contribution

For the next contribution, the use of the PAL REEM robot was no longer possible. The functioning of the robot was cut short by damage occurring during the transition to an external location. This meant to continue any further iterations and evaluation of the methodology, a new robot and supporting organisation would have to be found.

The research project team transitioned to an internally owned Pepper Robot and partnered with JobsforNSW, a government organisation, to undertake the next design study iteration.

CHAPTER 8

SOCIAL ROBOTS IN GOVERNMENT SERVICE APPLICATIONS

"Privacy, properly defined, is a necessary condition for human well-being or flourishing and not a mere interest." Adam Moore [272, p. 41]

Chapter Summary *Design Study 2: Designing for privacy in HRI. Location: Sydney Startup Hub. My Role: Researcher, Facilitator, Interaction Designer.*

Purpose *Undertake the process of identifying, designing, developing and implementing a social robot application for a government organisation, with specific focus on privacy considerations.*

Methodology *The UX-HRI framework is used to discover potential applications that could enhance the experience for entrepreneurs and visitors to the centre.*

Findings *The process is successful in discovering potential applications, however, this results in a trial of a social robot privacy management system. The system allows users to be identified by the robot, using either face recognition or QR code, and meets privacy regulation regarding collection of personal information.*

Contributors *This chapter incorporates the work and findings produced in collaboration with: Jonathan Vitale, Sarita Herse, Syed Ali Raza, Srinivas Madhisetty, Le Kang, The Duc Vu, Benjamin Johnston, and Mary-Anne Williams; published in the 2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (pp. 1-8). IEEE. [381]*

8.1 Privacy Sensitive Robotics

This chapter further refines the social robot application methodology, UX-HRI, forged in the previous design study. The environment in which this next design study occurs is a public innovation space for entrepreneurs. Contrary to the previous study, the assumptions make no limits on the collection of personal data. In this study, the robot is intended to be used as a shared public resource which may require identity authentication for some services. By using a human-centred design approach *i.e.* following the social robot application UX-HRI design process, it was possible to ascertain what type of applications may be suitable for the considered environment. The robot plays a role in the process, collecting votes for the best applications from those present within the location, while also providing them an opportunity to interact. Additionally included are the learnings from the previous design study, expanding the methodology; an on-site, on-the-fly development stage which allows for adjustment and changes to the actions and behaviour of the robot based on user feedback within the situated context. These additions to the methodology provide mechanisms for authentic and extemporaneous evaluation by users and improvement to the application under trial.

The design study provides two purposes. Firstly, it provides further opportunities for refinement of the social robot application UX-HRI methodology. Secondly, it is the first instantiation of a novel social robot application design that incorporates privacy as a vital component of the application, via following a Privacy-by-Design approach. This enables a contribution to the growing literature regarding privacy sensitive robotics design and a reusable template for identity management of users of a shared social robot application resource.

8.1.1 Design Assumptions

The assumptions for this project are listed below. Differently from the previous study, in this project the research team worked with the JobsforNSW organisation, a government service. As such our beginning assumptions are slightly different to the previous commercial applications. The list from Chapter 7, is repeated here with the additional assumptions in italics.

1. Any social robot applications are designed and developed to function in a professional manner for deployment, using today's technology and capabilities. This

means no Wizard-of-Oz techniques, no robot operator controlling and assisting interactions.

2. The application must be stand-alone and able to be used again and again by end-users without intervention by a practitioner or researcher, to reset or restart the application interaction.

3. The application must be able to be used without human guidance. It has to be designed in such a way that end users can intuitively, or with guidance from the robot, make sense of how to use the application.

4. Any sensing or processing must be done as much as possible on-board the robot without the use of auxiliary equipment that would not be present in a real world deployment of the technology.

5. Any Artificial Intelligence systems used must provide a sufficient confidence and accuracy to be able to sensibly guide any decision making required by the robot or by users.

6. Repeatable and consistent functioning is expected at all times that the robot is deployed for use with end-users. There shouldn't be any bugs in the software. Any unexpected malfunctions or lack of capability by the robot will be managed in a graceful fallback or degradation manner.

7. Any visual design will be professional and in a manner that *is suitably representative of the organisation. This also includes branding of the robot and tablet screen with a logo and identity.*

8. The robot will be designed to behave in a manner that is respectful and polite, as would be expected for *any customer-facing employee of the organisation. This includes gesturing, language (inclusive and positive vocabulary) and tone.*

9. All functionality will meet privacy legislation requirements. *Data management practices will comply with the Australian Privacy Principles.*

10. The value the prototype application is intended to provide to service users is real, based on genuine need. There should be a real world benefit to the task the robot is performing.

11. *The robot application must be designed to be accessible as possible, with alternative options for a broad spectrum of differing capabilities and needs.*

8.2 Combining Privacy-by-Design and UX-HRI methodology

As presented in the previous chapter, creating real world social robot applications for public spaces requires careful study and understanding of the environment in which the robot is to be deployed, and ensuring a viable application and a positive customer experience for the situational context. Social robots can create experiences unique from other technologies through a combination of communicating in a socially natural, human fashion [43] and all the psychological aspects this type of interaction includes, while also digitally communicating and providing an interface to technological devices around them. The challenge is to create an application able to ensure the best customer service and experience in the considered environment, that utilises both social and digital communication in an appropriate fashion. This is especially important in customer service situations, where reluctance to use the new technology due to a lack of trust in the new system, may arise [172].

In this design study potential applications are explored in a government managed centre for innovation and startups, run by JobsforNSW. The UX-HRI methodology for human-robot interaction was used to uncover unmet user needs and insights. These were used to determine viable social robot applications to enhance the user experience for entrepreneurs and visitors within the centre. In the process of application discovery, it was identified that before any type of real world application for prototyping and use in the location could be provided, the issue of privacy management had to be addressed. The proposed applications would require permission of users to store their personal information and, as privacy law required, the ability of the user to view, edit and delete any information held. As such, the first iteration prototype application addresses the privacy management required for a social robot application providing personalised services in a public space.

The need for user feedback and application design were combined, resulting in the prototype application providing two purposes, 1) trialling of a novel, real world privacy sensitive identity management system for use in the considered context and 2) a method by which end users can provide feedback and vote on the proposed application services they would be most likely to use. In this way, people were enabled to interact and gain firsthand experience with the robot, situated in the environment of use, and influenced by the corresponding social norms. This ensured any feedback received was not just from vignettes requiring imagination by the user on how they may, or may not, behave in a

suppositional scenario. How users say they will behave regarding personal information use and how they actually behave in real life can be quite different, according to the privacy paradox [288]. Instead, with the prototype application, users would interact and perceive the real life risk of using the social robot in their day-to-day environment, furthering the external validity of the applications and study.

The design process took place in two distinct stages, which corresponded with the ethics requirements for the study. As the application to be used for the study is unknown before visiting and interviewing people in the environment, it is not possible to initially request ethics approval for the (future) application study. Instead, two ethics approvals are required. The first ethics approval is for the needfinding interviews and application(s) conceptualisation. The second ethics approval is for the testing of the prototype concept applications in the location and the corresponding hypothesis examination this involves.

The first stage of the process involved following steps from the initial UX-HRI process: 1) Define the Challenge 2) Observe 3) Form insights 4) Frame Opportunities and 5) Brainstorm. The challenge was broadly defined as *"How might we use social robots to enhance the customer experience in the Sydney Startup Hub environment?"* The observation and need finding undertaken at the Startup Hub followed the same approach as the previous airport study. Everyone present in the environment was relevant to the interviewing. Two concept applications were chosen from the brainstorming process and story-boarded, for presentation to the Startup Hub organisation for proposed development. The presentation document is provided in the Appendix A.

However, both proposed concept applications required identification of the person interacting with the robot to provide access to personalised services. The concept applications had been designed using a Privacy-by-Design approach (PbD) throughout conceptualisation and identified that creation of a privacy protecting identity authentication system was required. Indeed, the concept applications could not meet privacy requirements without this functionality. Research of available literature revealed a lack in social robot applications that have provided this functionality. There was no information on how this necessary social interaction could be managed in a manner which would meet real-world privacy legislation. Hence the project team's development efforts would instead address this challenge first, and create a system which afforded this privacy protecting data collection ability to the robot. A brief, on-site system test of the robot revealed the extent of work required for such a system. The initial onsite test was a very short exercise (approximately 4-5 hours) where the robot was set-up with Wifi, tested for connectivity, and a short Question / Answering functionality application on the robot

was run to test acoustics and assess if the robot could hear properly in the space.

It was determined that the development complexity of the user registration system would be significant, limiting the development time available for the full, proposed applications. Thus, the second stage of the project instead concentrated on building and testing this system for registering a personal identity with the robot. The system would also allow users an opportunity to provide feedback on the proposed, final applications for the robot. This ensured the findings would not be lost from the initial stage and would in fact be strengthened with feedback from users interacting in the situated context.

Before the experimental study began, the robot was briefly trialled on-site and minor adjustments to the robot behaviours, speech and placements were made, based on user feedback from unstructured interactions with the robot. This was in line with the finding from the previous airport study that there would be a benefit to on-site adaptation. Items included adjusting the height at which the robot would gaze, where the robot would look during interacting and when not interacting, the timing of staying still for a photo, extraneous screen removal and crafting answers for non-obvious yet popular questions, for example *"Bring me a coffee"*. The robot would reply to such a question with, *"No I am not your servant. The cafe is just over near the windows."* Importantly, given the industrial, concrete floor and exposed ceilings of the environment, the best possible placement and the extent for audio capture by the robot was also determined. These small but vital changes, based on verbal user feedback, and immediately implemented and deployed on the robot, ensured the study would run smoothly.

The identity authentication system was created to provide personalised services to users and demonstrate the beginnings of social intelligence by the robot for social interactions. In fact, without the system, a social robot interacting with the multiple users visiting the considered public space would not legally be able to provide personalised services to users, or be sociable.

Importantly, given the nature of the robot's utility in the public, government managed environment, it was required for the system to be inclusive, i.e. guarantee fair access to its services within that environment *and* comply with the local privacy laws. Hence the research question became for the application study: *"How might we design a registration and login process that responsibly collects necessary private information while adhering to privacy regulations and providing inclusive services?"*

In the following section, the research question is addressed with a discussion on the challenges of privacy, the importance of transparency and the impact of trust for robots deployed as shared resources in a human-centred public environment. Following

that, the motivation and justification for the design choices of the registration system for identity authentication are presented.

8.2.1 Robots as shared resources: Privacy, transparency and trust

As robotic technology and platforms continue to develop in complexity, function and scale, it is vital that responsible methods for data collection that protect privacy and preserve fairness, are developed [383, 396, 397]. Article 12 in the United Nation's Universal Declaration of Human Rights (UDHR) details the Right to Privacy of all people [148]. Respecting the human right to privacy is a significant challenge for roboticists as robots are effectively powerful surveillance devices [55] able to collect visual, audio and situational data, for analysing and responding to their environment. The difficulty is to promote adoption of robots, a data-intensive collection technology, while also respecting individuals' rights.

When a robot is installed as a shared resource in a public space and provides people access to personalised services, the subsequent collection of customer data brings consumer privacy issues to the fore. This is particularly the case for the collection of sensitive biometric information, such as facial information required for face recognition technologies. Collecting face data requires explicit consent from the user under European regulations, with increased regulation of consumer biometric data expected from other countries [411].

To meet required privacy regulations, users need to be aware of how collected personal information will be used, retained and shared (by the organisation behind the technology), and to understand the privacy implications of using the system [396]. Transparency assists users' risk assessment and their decision of whether to trust, and consequently adopt, the designed robot application. In addition, transparency has been demonstrated to positively impact on users' experience, as was discovered in Chapter 5 [396].

Previous research has outlined transparency as a tool to promote user trust of new systems and the companies making them; with this being particularly true for systems collecting private user information [82]. It has been suggested that in this context, a strengthening of consumer trust towards an organisation grows from the quality disclosures that result from transparent protocols [314, 341]. This may enhance the perceived trustworthiness of the organisation to users, so long as the company abides by their own outlined practices [81].

The impact of consumer trust on the adoption of new technologies is a genuine and growing concern within social robotics. If users do not trust a new system, its acceptance and integration into the public may be met with resistance [172]. When collecting personal information, trust affects the users willingness to risk disclosing private information to a system [82]. It is imperative that the organisations behind these technologies strive to build strong, long-term relationships with users; allowing them to feel comfortable enough to rely on these institutions to protect their interests and information [84, 314].

Issues surrounding trust towards new technologies may occur due to various factors. Most notably, the perceived competency of a new or newly emerging technology can have great impact on user trust [133]. The current social climate surrounding autonomous cars is a clear, real-world example [212]. Additionally, the trust (or distrust) felt by a consumer towards a company can have flow on effects towards the products that the company designs and develops [82].

Developing a responsible social robot application for personalised use in a shared environment requires strong consideration of possible privacy impacts. The transparency practices used should also be examined for their impact on user's trust and subsequent adoption of the new system.

8.2.2 Registration System Design

User registration systems for login processes are nothing new. People register personal details with websites, mobile apps and company software everyday, and the practice is quite established. However, registering as a user for a robotic application that uses facial recognition is an undertaking that is not common and it introduces additional challenges in privacy provision.

In the wild studies for robots that use registration systems for personalised services are not new but few in number. Glas *et al.* undertook a study in a shopping mall that used a mobile application to register users, enabling them to request the services of a baggage carrying robot [147]. However, users were hired for the study, instructed what tasks to perform and were not general customers of the shopping mall. Hybrid-cloud systems that combine robotics platforms, web portals and mobile apps, such as that by Fiorini *et al.* [121], are more recent yet still limited in number, although of great interest in the aged care and medical health domain.

The main differentiation from the aforementioned works with this study is to offer users different methods to access the system to guarantee maximum inclusiveness, and

a way for users to manage their information, that complies with locals laws and privacy regulations regarding sensitive data.

To determine the right design for the registration system, Nissenbaum's theory of "contextual integrity" is used, which suggests that privacy expectations are mainly determined by social norms of information flow for specific contexts [287]. Therefore the user registration system design is concentrated on the idea that privacy expectations are context-specific, and that the information to be collected must be germane to the particular purpose of use and specific community, based on social norms for the information flow that may be expected in the environment. However, as social robots are a new experience for most people, social norms for the information flow between users and a social robot have not yet been established. Hence, it is assumed that there will be a certain distribution of the population [217] that will be reluctant to use their face as their personal identity due to their risk assessment of the unfamiliar situational context, with a possible lack of trust in the management of their information. Instead, identified is an alternative methodology to provide access to the services that reduces the amount of sensitive information required from the user. Users that did not want to register with their face were offered a QR code instead. Users that selected the latter option were not automatically recognised by the robot. Instead they gained access by showing a QR code from their smartphones to the robot. The QR code alternative impacts the user experience, as the login system is less convenient, less immediate and less social (between robot and user), but still guarantees access to the provided services, thus enabling maximum inclusiveness among all users.

Performing an evaluation of possible privacy impacts and risks, as per a Privacy-by-Design approach [85], and as put forward in Chapter 6, allowed identifying how personal information would flow in the proposed robot application and identified options for maintaining contextual integrity, minimising negative privacy and UX impacts. This included determining which type of personal information should be provided by the user (name, face information, e-mail, mobile), when (which step of the process), and where it is appropriate to do so (on the robot on-site, or elsewhere on a different device, e.g. mobile or laptop). Using the seven types of privacy categorisation by Finn *et al.*, [120] privacy of the person, privacy of personal communication, privacy of data and image, privacy of behaviour and action, privacy of thoughts and feelings, privacy of association (includes group privacy), and privacy of location and space, provided a lens with which to view possible impacts on privacy.

For organisations handling Personally Identifiable Information (PII), a common

practice to ensure conformity to privacy legislature is to undertake a Privacy Impact Assessment (PIA). In Australia, the privacy guidelines describe 10 steps to undertaking a Privacy Impact Assessment [12]. These are:

1. Threshold assessment
2. Plan the PIA
3. Describe the project
4. Identify and consult with stakeholders
5. Map information flows
6. Privacy impact analysis and compliance check
7. Privacy management — addressing risks
8. Recommendations
9. Report
10. Respond and review.

For followers of privacy developments in Europe and the recently implemented General Data Protection Regulation (GDPR) [312], a PIA is more generally referred to as a Data Protection Impact Assessment (DPIA), however the practices may be considered essentially the same [33]. The GDPR provides guidelines on DPIA's and describes a DPIA as *"a process for building and demonstrating compliance"* [86, p. 4]. The DPIA is not considered mandatory, it is only necessary when the processing *"is likely to result in a high risk to the rights and freedoms of natural persons" (Article 35(1), see III.B.a)* [86, p. 18]. The DPIA requirements are quite broad and generic, and difficult to apply in practice. Bisztray and Gruschka compared the methods used for conducting a DPIA and discovered the ISO standard 29134:2017 has the best content and framework [33]. It provides concrete steps for conducting a DPIA. These are provided as the following:

1. Identify information flows of personally identifying information (PII)
2. Analyse the implications of the use cases
3. Determine the relevant privacy safeguarding requirements
4. Assess privacy risks

5. Prepare for treating privacy risks.

Using either of the previously described methods, a PIA or a DPIA, will allow a comprehensive assessment of risks.

However, what these methods lack, in their determining of privacy risks and safeguards, is the human aspect and corresponding moral and political factors. How people perceive privacy in different contexts and situations determines the behaviours, values and norms for what data is shared in which context [286]. This is especially the case when interacting with a social robot, where people may anthropomorphise the robot and may have different expectations of personal data use due to the social nature of the interaction. Hence Nissenbaum's Contextul Integrity (CI) privacy theory [287] provides an ideal framework. Nissenbaum puts forward nine decision heuristics: "

1. *Identify the new practice in terms of information flows.*
2. *Identify the prevailing context. Establish context at a familiar level of generality (e.g., "health care") and identify potential impacts from contexts nested within it, such as "teaching hospital."*
3. *Identify information subject, senders and recipients.*
4. *Identify transmission principles.*
5. *Locate applicable entrenched informational norms and identify significant points of departure...*
6. *Prima facie assessment: There may be various ways a system or practice defies entrenched norms... A breach of informational norms yields a prima facie judgment that contextual integrity has been violated because presumption favors the entrenched practice.*
7. *Evaluation I: Consider moral and political factors affected by the practice in question. What might be the harms, the threats to autonomy and freedom? What might be the effects on power structures, implications for justice, fairness, equality, social hierarchy, democracy, and so on?...*
8. *Evaluation II: Ask how the system or practices directly impinge on values, goals, and ends of the context. In addition, consider the meaning or significance of moral and political factors in light of contextual values, ends, purposes, and goals...*

9. *On the basis of these findings, contextual integrity recommends in favor of or against systems or practices under study... "[287, p. 182]*

Nissenbaum's theory defines three key parameters: Information Types, Actors and Transmission Principles. These three parameters are independent of each other and each with their own range of parameters. So for example in this study, it was deemed the transmission of a person's biometric template (information type) to any other entity (actors) other than the robot, may violate expected contextual norms to a degree that people may not use the proposed system. Sending personal biometric data to a centralised database additionally increases the security risk due to threat of interception and possible future misuse, such as surveillance, which itself may impinge on human rights and dignity. Thus the system kept all aspects of the facial recognition system locally on the robot. Further considerations on security and minimising identity misuse by bad actors meant additionally creating a two-step registration process. Hence the robot registration system is diversely cross-platform: combining robotic, mobile and web platforms.

The success of the proposed system was measured by counting the number of people that completed the registration process on the robot by choosing either to register with their face or with a QR code, as opposed to leaving the registration process due to a lack of desirable alternatives. Also measured were the sentiments and feelings of individuals that registered, to monitor the functionalities to maintain, abandon and/or pivot, as per the design methodology put forward in the previous chapter and published [382]. Furthermore, the proposed concept applications were measured for how likely people are to use the services, the service they would use and why.

Hence a research contribution for this second stage of the design study is the provision and discussion of a viable design for a cross-platform registration and login process for social robot applications able to 1) maximise the inclusiveness of the system among the targeted audience; 2) meet privacy regulations regarding the collection, storage and use of sensitive information; 3) elicit positive sentiment from users regarding the registration process experience and 4) enable users a choice in selecting the applications for the robot to provide. The study design is described in the following section.

8.3 Methodology

The study was situated at the Sydney Startup Hub (SSH), a government managed centre for startups and innovation. Differently to the previous design study, the humanoid Pepper robot was used. The robot was placed next to the reception desk where it was

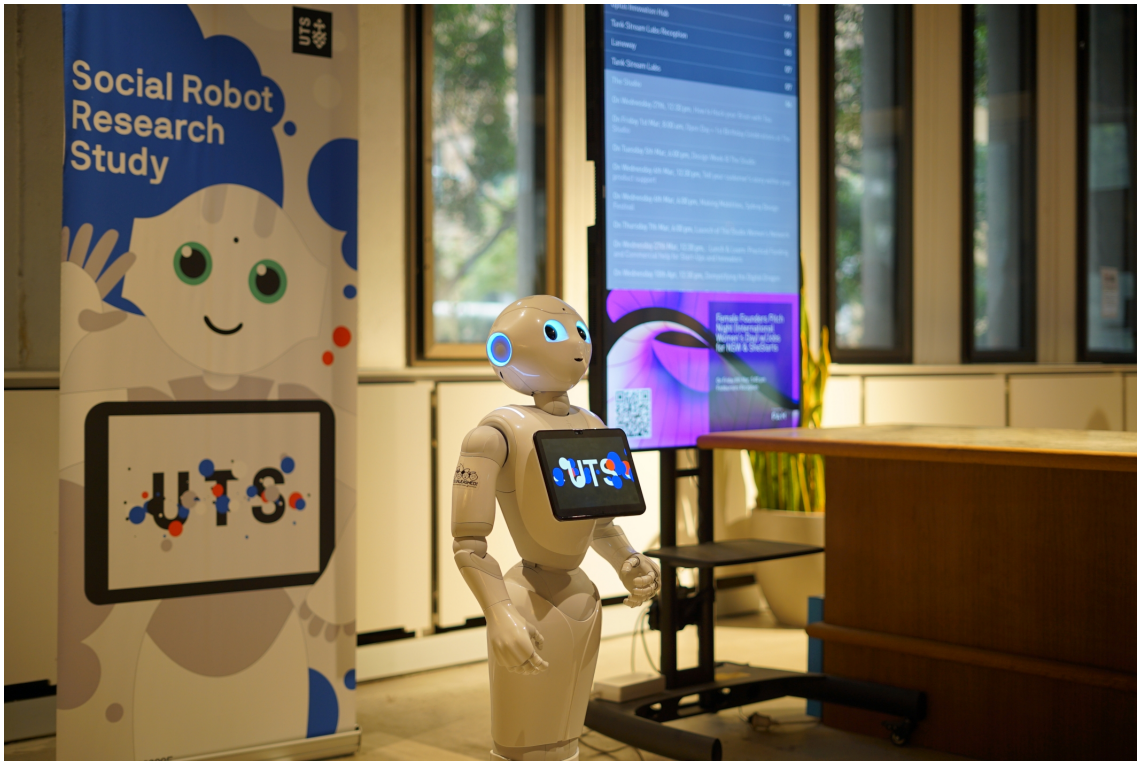


Figure 8.1: The location of the robot during the study.

visible by people entering the reception area. Behind the robot was a vertical coloured banner alerting people to the presence of a social robot research study endorsed by logo of the university sponsoring the study (Figure 8.1). The researchers monitored the robot from a seating area next to the reception desk. The robot offered users two options to register their identity: 1) by capturing their facial information, or 2) by sending a QR code to show to the robot as login. The study exhibited the robot at the location during business hours (i.e. Monday to Friday from 10am to 5pm) for a total of seven business days.

8.3.1 Participants

SSH visitors were free to approach the robot, which was programmed to greet and engage with the users detected at approximately 1.2 meters from the robot front-facing camera. When a user was detected and greeted by the robot, the user was invited to take part in the study. If not interested, users were free to leave.

If the participant remained engaged with the robot to continue the interaction, the

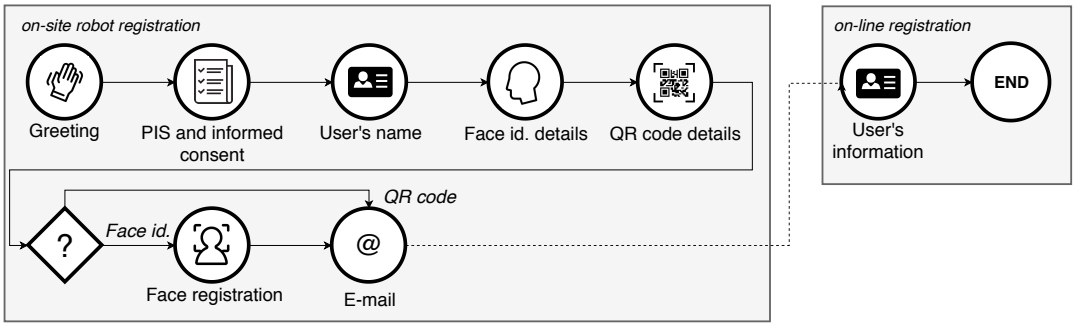


Figure 8.2: Information flow from on-site robot to on-line website.

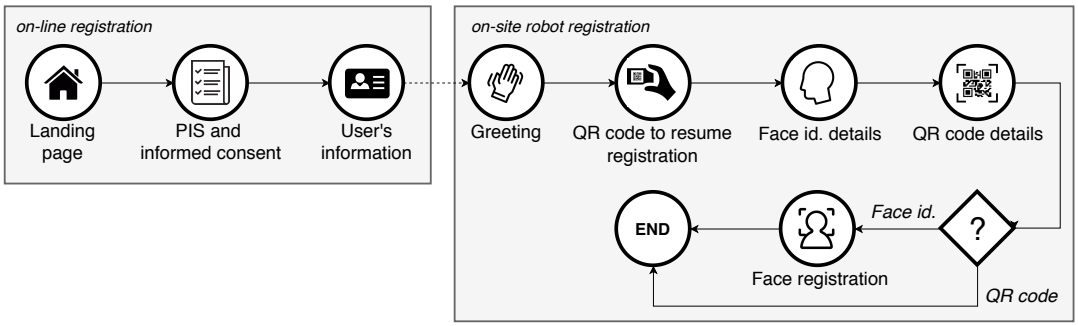


Figure 8.3: Information flow from on-line website to on-site robot.

researchers approached the participant to provide them with more information about the research study and a participant information sheet, as per protocol approved by the Ethics Committee of the University of Technology Sydney (UTS HREC ETH18-3158). The participants then interacted with the robot without receiving instructions by the researchers. The robot was completely autonomous. Before proceeding with the registration process, the robot asked the participants to read a digital consent form and to press a button to either agree or not to continue with the research study. To accept the consent form the participants had to be over 18 years old and able to communicate in English. After giving informed consent, the interaction continued with the registration process as described in Section 8.3.4.1. Participants registering on the robot were asked to verify their identity and complete their registration on-line.

Participants were able to start the registration process from the on-line website, and then complete it by visiting the robot on-site. In this case, the informed consent was presented during the on-line registration process. Hence, included in this study were all participants' that accepted the digital consent form on either the robot or the on-line website and they:

1. fully completed the registration process on the robot; *OR*

2. fully completed the registration process on the on-line website; *OR*

3. initiated the registration process on the robot but left after receiving information about the face registration option.

The third condition was necessary to measure how many participants left the registration process after receiving details about the use of face recognition, which is considered sensitive data collection. A total of 103 participants interacted with the robot and an additional 3 participants registered on-line; thus, a total of 106 participants were included in the study. For this study, the gender and age group of the participants was not collected.

8.3.2 Measures

To investigate users' registration preferences, the number of people who decided to register with their face, to use the QR code, and to leave the registration process when becoming aware of the offered options for completing their registration was measured. A measure of success for the design would be to maximise the number of users that completed the registration process by choosing one of the two available alternatives.

To better understand the users' choices and evaluate the user experience of the registration process, qualitative feedback was collected from the registered users through a post-interaction survey. The survey included the following items:

- A 5-point response question ranging from "very particular" to "very open" measuring how participants described themselves with regards to sharing their private information;

- An open-ended question asking participants to provide feedback regarding the experience of registering with the robot;

- An open-ended question asking participants to describe why they selected face identification or QR code.

Additionally, users were invited to provide feedback on the two suggested application services the robot was to provide.

- Two 7-point response questions ranging from “extremely likely” to “extremely unlikely” measuring how participants rated how likely they would be to use the service (Pepper Hub Check-In and Pepper Hub Founder Feedback)
- A multiple choice question asking which service they think should be implemented at the Startup Hub. "Pepper Hub Check-In", "Pepper Hub Founder Feedback" or "Neither - something different";
- An open-ended question asking participants to describe why they selected the above answer for which service should be implemented.

These measures, together with the observations in the field, provided valuable insights to assess the viability and gain user feedback for the proposed applications.

8.3.3 On-line Pilot Study

An on-line pilot study was run on Amazon Mechanical Turk to test if the designed alternatives to register with the robot were suitable for the considered study.

Video was recorded of a Pepper robot enacting part of the registration process employed in the study. In the on-line pilot study, the robot was introduced as a device situated in the participant’s work environment allowing access to personalised services for the workspace. On-line participants and the study participants obtained the same details about the two registration alternatives.

The on-line pilot study participant was asked to select to register with either face identification or QR code and to explain what motivated their choice with an open-ended question. Of particular interest was to discover the presence of ceiling or floor effects among the two alternatives and the users’ motivations for their choices.

From the total 274 participants about 74% selected to register with face identification and the remaining 26% with QR code. No ceiling or floor effects for either of the options were found. The most recurrent motivation among people choosing face identification was its ease of use and time convenience, whereas participants choosing QR code suggested that this option was less privacy intrusive and more reliable in dealing with look-alike individuals.

8.3.4 Registration Process

The registration process required two steps: 1) registering a password and entering some personal information on an on-line website deployed specifically for this study; 2)

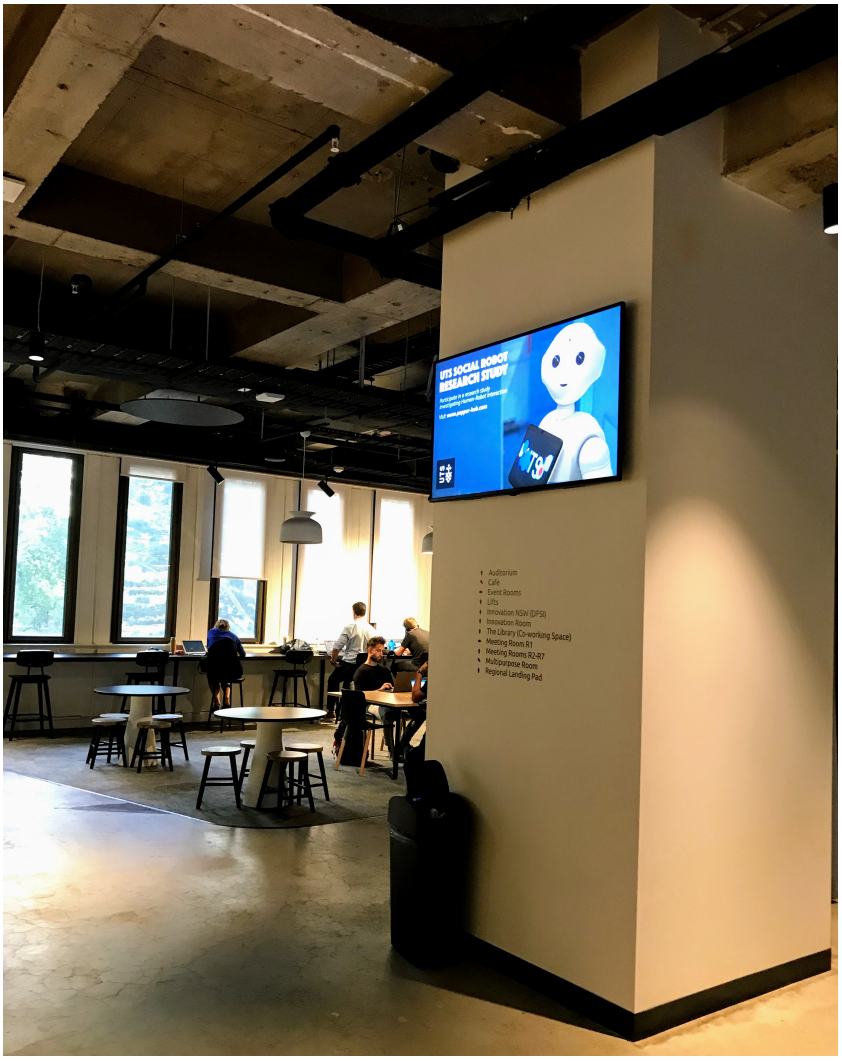


Figure 8.4: Advertising of Social robot research study on LCD screens

registering the access preference to the system (i.e. face identification or QR code) by physically interacting with the robot on-site. People were free to choose the order and when to perform such steps. However, users were not able to access the services offered by the robot until they completed both required steps. Figures 8.2 and 8.3 summarise the two possible interaction flows for the full registration process. The online registration option was advertised in an email to the Startup Hub residents and also displayed as a banner ad on the various LCD TVs around the location, see Figure 8.4.

8.3.4.1 On-site Robot Registration

When the robot detected the face of a person at approximately 1.2 meters, it greeted the users while briefing them about the research study. Meanwhile, the face recognition system analysed and compared the face of the current user with previously registered faces. If the system found a match with a face in the robot's database, the robot paused then acknowledged the user by name. If the recognised user had also completed the on-line step, the robot allowed the user to access a menu with a list of provided services. Otherwise, the user was reminded to complete the on-line registration before being granted access to the services.

If the face recognition system did not match the user's face with any of the registered faces, the robot offered the user the option to continue with a QR code or to register as a new user. Users received a valid QR code to use when completing the on-line registration process. The QR code was used in three scenarios: 1) by users registered only on-line to resume and complete their registration process on the robot; 2) by users selecting QR code as their access method and completing the registration on-line; 3) by users selecting face identification as access method and completing the registration on-line, but unrecognised by the robot. This latter option was used as a fallback for managing false rejections by the face recognition system.

New users selecting to register on the robot were first asked to provide their name, so the robot correctly addressed them during the rest of the process. This step was neglected for users that had already completed the on-line registration.

The robot then provided information on how the face recognition system worked and the employed privacy policies. The robot said: "There are two options. First option is registering with your face as the log in. I convert a photo of your face to the equivalent of a digital pin. I keep those numbers, not your actual photo, securely in my database". The robot's tablet displayed a picture of a face converted into a vector of numbers and a link to the privacy policy. This step was crucial for adhering to current privacy legislation and to enhance the user experience, as evidenced from our previous studies [383, 396]. Following this, the robot provided details on how QR code access worked. The robot said: "Second option is using a QR code. I will send you a QR code on your phone, you can show me to make your services available". The robot's tablet was showing an animation of a hand holding a smartphone with a QR code moving towards the robot's forehead camera.

After presenting the two available alternatives to complete the registration, namely face identification and QR code, the robot asked the participant to select their preferred access method. If the user selected face identification, the robot asked them to stand still

and look into the forehead camera to register their face. If the user selected QR code this step was skipped.

To complete the registration process, the user needed to provide a valid e-mail address to receive a link to complete the registration on-line. This step was skipped for users that had already completed the on-line registration.

Importantly, all registered faces were stored locally on the robot and never transmitted on the internet. This is consistent with how facial recognition for mobile phone authentication is conducted, known as *"match-on-device"*, where any biometric data is kept on device and not transmitted to a centralised or remote location [160]. Also, the system removed all other information collected from users at the end of the registration process. Again this follows security practice for biometric data, to avoid storing personal details together with biometric data, preventing the ability to map the information back to a specific individual.

8.3.4.2 On-line Registration

The on-line registration website opened with a landing page showing a button to login for registered users and a button to register as a new user. The landing page also offered information about the Pepper robot, the research study, the research team and the research partners.

Users selecting to register were asked to read a participant information sheet and to provide consent before proceeding. This step was not required by users that had already completed registration on the robot, since they had already been asked to do so while registering on-site.

Users were then asked to provide an e-mail address, a password, their name (pre-filled if already supplied during the registration process from the robot on-site) and, optionally, a mobile number and the name of their business.

Users completing the registration on-line were able to edit or remove their profile at any time. They were also able to retrieve a QR code to complete the registration on the robot (and to use it to access the robot services, if they decided not to use face identification). Through the website, users were also able to answer our post-interaction survey and select their choice of which services (applications) the robot should provide. In addition, the website provided access to our privacy policy.

8.4 Results

Counts of participants interacting with the robot were recorded, for participants accepting the consent form and either 1) completing the registration on the robot or 2) abandoning it after getting to know details about the face identification process. Table 8.1 reports the number of participants interacting with the robot and included in the study, together with their preference for registering with the robot.

Table 8.1: Participants and their access method preference.

	Face identification	**QR code**	**Left**	**Total**
N. participants	78	18	7	103
% participants	75.73%	17.47%	6.80%	100%

Among the participants completing the registration on the robot, 78 out of 96 (81.25%) selected face identification. This choice was then tested to see if it was above chance level by employing a single sample z-test for proportions. The selection of face identification against QR code was significantly above chance ($p < 0.01$).

Due to the two-step registration process, the participants fall into two main groups: 1) those initiating the two-steps registration process from the on-line website, and 2) those initiating the two-step registration process directly on the robot. Therefore, the number of participants that either 1) completed both the required steps or 2) completed only one of the two required steps, was collected for each of the groups. Tables 8.2 and 8.3 show the number of participants initiating the registration process from the on-line website, and the number of participants initiating the process on the robot, respectively.

Table 8.2: Participants starting from the on-line registration.

	Two-steps completed	**Two-steps not completed**
N. participants	0	3
% participants	0%	100%

It was tested whether the chosen registration flow (web first vs robot first) and the outcome of the registration (completed vs not completed) offered any dependency. Given the small sample size of users initiating their registration process from the website, a Fisher's exact test was conducted which suggested that the relation between these variables was not significant ($p = 0.0844$).

A chi-square test of independence was performed to examine the relation between the chosen access methodology (face identification vs QR code) and the registration

Table 8.3: Participants starting from the robot registration.

	Two-steps completed		
	Face identification	**QR code**	**Subtotal**
N. participants	44	11	55
% participants	45.83%	11.46%	57.29%
	Two-steps not completed		
	Face identification	**QR code**	**Subtotal**
N. participants	34	7	41
% participants	35.42%	7.29%	42.71%

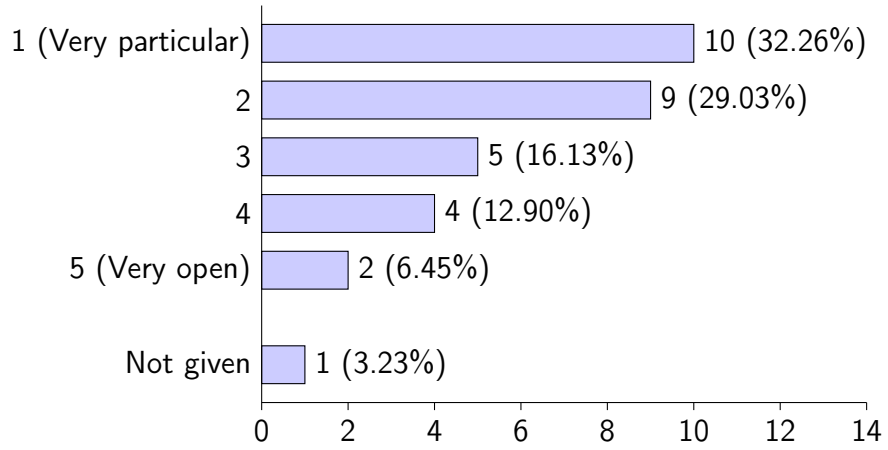


Figure 8.5: Self-report of participants' private information disclosure level.

outcome (completed vs not completed) within the group of participants initiating the registration process on the robot. The relation between these variables was not significant, $\chi^2(1, N = 96) = 0.1321$, $p = 0.7163$.

Among the 55 participants completing the two-step registration process, only 31 of them (56.36%) completed the post-interaction on-line survey. Furthermore, among the participants completing the on-line survey, 28 participants were those that selected face identification, whereas only 3 were those that selected QR code access.

The post-interaction survey asked participants to rate themselves on how open they are to sharing their private information on a scale from 1 ("very particular") to 5 ("very open"). Figure 8.5 shows the distribution of their answers.

Participants were also asked to complete the on-line survey to provide feedback about their robot interaction experience. When analysing the provided feedback the adjectives used to describe the experience were extracted and categorised into positive adjectives or negative ones. Some of the comments included multiple adjectives. Table 8.4 shows the

adjectives describing the experience with the robot.

Table 8.4: Adjective counts as provided by participants to describe their interaction with the robot.

Positive adjectives						
Fun	**Great**	**Easy**	**Straightforward**	**Fast**	**Engaging**	**Novel**
4	3	2	2	1	1	1
Unique	**Surprising**	**Sociable**	**Reasonable**	**User-friendly**	**Simple**	
1	1	1	1	1	1	

Negative adjectives					
Slow	**Talkative**	**Unresponsive**	**Long**	**Instructional**	**Limited**
6	1	1	1	1	1

Participants described their experience with the robot by using a total of 19 adjectives: 13 denoting a positive experience and 6 denoting a negative one. In total, the adjectives were used 31 times in the participants' comments, with a count of 20 denoting a positive experience (64.52%) and 11 denoting a negative one (35.48%). Three participants also expressed discomfort when interacting with the robot due to the short height of the robot and their need to bend when typing their name or the e-mail address. Furthermore, four participants provided an adjective to describe the robot in their feedback. Pepper was described as charming, cute, adorable/friendly, and intimidating.

Finally, the participants completing the on-line survey were asked to justify why they selected face identification or QR code during their registration. By reading the provided motivations, seven main reasons were identified: 1) convenience/accessibility; 2) novelty; 3) curiosity; 4) social nature of the interaction; 5) fun; 6) trust; and 7) security. Some of the provided comments reported multiple explanations, that fell into more than one identified category. The results of this qualitative analysis are shown in Table 8.5.

Table 8.5: Participants' motivations for choosing face identification or QR code.

	Face identification	**QR code**
Convenience/accessibility	20	1
Novelty	4	0
Curiosity	3	0
Social nature of the interaction	2	0
Fun	1	0
Trust	1	2
Security	1	0

Interestingly, two of the three participants that selected QR code justified their choice by suggesting that they did not have sufficient trust to register their face. Answers are reported here for convenience:

"I choose QR code because I don't trust face recognition system if they can get hacked easily";

"I won't give my Face ID to a service provider I can't fully trust".

With regard to the proposed application services to be provided by the robot, participants were more likely to use the Pepper Hub Check-in service as opposed to the Pepper Hub Founder feedback, as shown in Table 8.6. A common reason provided for this choice was that it would be easy and convenient. As described by one user,

"I think it is a more applicable and ubiquitous interaction.";

Further suggestions for the Pepper services added to the Pepper Check-in theme, with Pepper providing wayfinding to meeting rooms, a meeting minutes scribe and booking of meeting rooms.

Table 8.6: Participants and their choice of service application.

	Check In	**Founder Feedback**	**Neither**	**Total**
N. participants	15	4	3	22
% participants	68.1%	18.2%	13.7%	100%

8.5 Discussion

The results clearly show a preference for face identification when registering with the system. In fact, 78 out of 96 participants (81.25%) who completed the registration process on the robot chose to register their face information instead of using a QR code. This choice was well above chance. Nevertheless, although face identification was the most privacy invasive option, the bar plot in Figure 8.5 shows that the majority of participants (more than 50%) answering our post-interaction survey rated themselves as "very particular" or "particular" when sharing their private information.

This effect indicates that the social robot application was able to successfully maintain contextual integrity [287] for the majority of participants. It was able to match privacy expectations for appropriate information flows so users were comfortable selecting face identification, even if they self reported as at least "particular" regarding their privacy. However, it is important to mention that the participants were aware that their face information was being collected by experimenters from a public university conducting a

research study and not for a commercial product. This factor may have reduced their privacy concerns towards the system [254], resulting in their decision to grant the robot permission to record their face information. In addition to that, it is also important to note that face identification technologies are becoming more pervasive in personal devices such as smartphones, tablet and laptops due to their easy, quick, effective and practical use [393]. This additional reason may further explain why a large majority of participants selected face identification. Indeed, by looking at Table 8.5, the majority of the motivations provided explain the choice for face identification because of its convenience in terms of ease-of-use, speed or accessibility. Besides that, novelty and curiosity also played a role in this choice. These results suggest that our participants were willing to give access to their private face information in exchange for an easier, quicker and more accessible login method; even if the system was not deployed on a personal device like a smartphone, but on a resource shared by visitors to a public space.

Nonetheless, 18 out of 103 participants interacting with the robot (17.48%) chose QR code. This option was a valid alternative to our system for users who may feel that providing their facial information was not within appropriate norms for information flow, motivating privacy concerns. Only 7 participants (6.80%) out of a total of 103 users interacting with the robot left the registration process before completing it. Two of the three participants that selected QR code and completed the post-interaction survey motivated their choice due to a lack of trust in granting the system access to their face information. Without providing the QR code as a viable alternative, the number of people leaving the registration process may have increased to 24.27% (18 participants for QR code, plus the 7 participants who left, out of 103 participants).

With respect to the number of participants completing both the two-step registration process (i.e. both robot and on-line registration), only 55 out of 99 participants (55.56%) who initiated and completed one of the steps required by the registration process (3 participants using the web and 96 participants from the robot) also completed the second step. Notably, none of the 3 users initiating the process from the on-line website completed the registration by visiting the robot on-site. Unfortunately, there was not a large enough distribution of participants across the groups to be able to make strong conclusions about any interaction between initiating the sign up from the on-line website vs robot and the completion of the registration process. However, the first results might suggest that when designing a cross-platform multi-step registration process for social robot applications, it is more effective to design an interaction flow that simply starts from the interaction with the robot. Analysis within the much larger sample of users initiating

and completing the registration process on the robot (96 participants) to examining the interactions between the chosen modality (i.e. face identification vs QR code) and the completion of the registration on-line was not significant. Evidence was not found to suggest that the chosen access method leads to a significantly different number of participants completing the second step. From a design perspective, this result suggests that the access methods play little or no role in users completing the second part of the registration process.

From the comments collected there was a general positive sentiment towards the designed experience. The majority of adjectives used were positive and used in the participants' comments 20 out of 31 total times (64.25%). Pepper was mostly described with positive qualities and the physical appearance and design of the robot may have played a role in shaping an overall positive experience for the participants. Importantly, the majority of negative comments were suggestive of a long and slow process to register with the robot. The interaction with the robot required a maximum of 5 minutes, during which the robot communicated details of the data collection process and the login system via several steps. Usually, when designing a commercial product, users are given control over acquiring details by means of a separate menu or button (i.e. 'disclaimer', 'more information' or 'how does it work?'). However, due to the experimental nature of the study it was needed to make sure that every participant acquired the same amount of information. This lead to a longer interaction, requiring multiple steps and additional clicks on the robot's tablet to complete the registration process, but gave the necessary high level of transparency.

Finally, from the feedback received from users regarding the proposed applications for Pepper in the location, the Check-in service was selected as the most likely to be used. Only 3 users suggested they would not use the service application and would prefer something different.

The main limitation of the study is the nature of the designed system. The participants knew the system was not a commercial application and that the collected data would be deleted after the completion of this study. This approach may have played a role in reducing people's privacy concern in registering their face, due to their inherent trust of researchers from a public University constrained by ethics procedures [254].

In addition, during this first design iteration, the focus is on the registration system. Although the robot was designed to provide valuable services for the situated context, such services were not deployed at this stage and instead users were asked only to provide feedback on which they would use. The robot only provided a few basic services,

such as telling jokes, recording feedback or allowing people to take selfies. This limitation may have played a role in reducing the proportion of participants that completed the two required registration steps.

Furthermore, while two-step authentication is becoming more commonly used, for example with Google sign in [1] and Apple IDs [2], it may be that not all participants understood the process in this context.

Finally, the robot employed for the study was a Pepper robot. The interaction behaviour of users, as well as their sentiments towards the registration process, may differ with the use of different types of robots.

8.6 Reflections and Learnings

This study required a considerable amount of work and several days in the field. However, this effort was rewarded with a total of 106 real users and many vital observations on human-robot interaction in the wild.

In this study, the investigation was limited to people's preferences when registering their identity to use a publicly available and shared social robot. It was found that the majority of people were comfortable registering their face information to gain access to the available services, but that a non-trivial proportion of people were not at ease with doing so. As such, the designed alternative to face identification, i.e. the use of a QR code, played a critical role in increasing the number of users adopting the technology. This is an important contribution to the development of future social robot applications, as many potential use cases will require the permission of the user to store sensitive information and such systems should promote the inclusion of as many users as possible by offering viable registration alternatives. The reported results provide evidence that designing for privacy with inclusiveness and transparency upfront leads to responsible social robot applications that can be trusted by users and consequently adopted by the majority of the population.

The design of the registration system for identity authentication using facial recognition in a shared social robot application was considered a success for the research team. By following theory and careful consideration of all the different ways in which privacy could be breached or impacted, facial recognition technology was used in a socially responsible manner that was trusted by users, as evidenced by the significant

[1] https://www.google.com.au/landing/2step/

[2] https://support.apple.com/en-au/HT204915

choice of face as the preferred authentication method. People reported the convenience of face recognition with the robot. Additionally, also noted by one participant, was the accessibility of this type of interaction. For people without the ability to easily manage a phone or type into an interface, facial recognition for identity authentication may be considered an ideal option. The design of social robot applications to improve accessibility for all users is a still to be explored area and vital for inclusive design. Areas where this may provide the most benefit are in healthcare services and an avenue which is explored in the following chapter.

8.6.1 Privacy Considerations—The social robot dilemma

A dilemma currently exists for social robot applications with the current political climate regarding facial recognition. Privacy groups are pushing for banning facial recognition technology, with bans occurring in places such as San Francisco [309] for government use. The European Commission is even considering[3] a 5-year ban on the use of facial recognition in public spaces [27]. Indeed, the European Data Protection Supervisor has stated that the use of facial recognition is *"an ethical question for a democratic society"* [414], potentially impinging on human dignity. The ramifications for civilians from state surveillance and private company misuse are great [35] and evidence of public concern for such misuse might be inferred by the participants in the study who voiced misgivings regarding the technology's use. However, for a social robot to be able to engage and interact with people in a socially natural fashion, it involves remembering a person and a person's name, so as to greet them appropriately. This is commonly performed using face recognition technology. Thus the dilemma: *How can the social robot possibly manage to build a social relationship if it cannot remember or identify with whom it is interacting with?*

The use of facial recognition has not yet been investigated for ways in which essential sociability can be managed in a manner consistent with privacy legislation. However, if the social robot application also includes personalised services, which understandably require some method of identity authentication, in that case, it is much easier to address, yet involves a significant amount of development and management.

It is with these issues in mind that the identity authentication system was designed. By using the UX-HRI approach of human-centred design practices and Privacy-by-Design, the creation of a social robot application that met with privacy legislation, yet

[3] At the time of writing this is not yet in place

still provided all the intended social functionality, convenience and accessible services, was possible. The decisions made and learnings from this particular application and environment instance can also apply to the class of the problem regarding the use of facial technology for social robots in public spaces. The learnings confirm and build on that which is suggested in the literature regarding ethical practice. These learnings are summarised as possible principles for design and discussed in the following section.

8.6.2 Application Considerations

1. **Avoid Surveillance** This takes two forms: 1) Reducing surveillance by physically bounding facial recognition to within a close proximity of the robot. 2) Situating the robot in a position so that people feel it is possible to pass by the robot without being surveilled, reducing fear of being surveilled.

   The intention with these two actions is to put users in control and avoid feelings of constant surveillance, as per a panopticon effect [137]. Additionally, it has been suggested that if people perceive they are being surveilled, they are less likely to confer trust on the surveilling organisation [422]. People must approach close to the robot for information processing, such as face recognition to be triggered and begin. Thus the user is put in control of the facial recognition occurring.

2. **Ensure Data Security** Reducing of security risk to reduce possible harms.

   The biometric data is stored on the robot and if hacked, cannot be matched to personal details. The biometric data is not shared or stored in any other location. No centralised database or cloud-based storage is used for biometric data. Mapping of information is anonymous and one way. This is similar to biometric practice with "match-on-device" technology [45, 160]. Furthermore, once the robot is no longer to be used in the location, the specified environment of use, the biometric data is wiped from the robot. The robot should have an end date for biometric data that deletes the data after a set time, as per biometric best practice [211].

3. **Provide Transparency** Be transparent.

   Provide information about all data handling and the measures taken to protect privacy to assist building trust. For example, the measures taken ensuring the security of data and the responsible handling of personal information, and the avoiding of unnecessary collection of data, should all be made known to the po-

tential user. This follows the Privacy-by-Design approach and, as established in Chapter 5, may improve the user experience.

4. **Establish Consistency** Be consistent in the behaviour and actions of the robot.

   People quickly ascertain at what distance the robot picks up on their passing and intention to engage. This forms an invisible zone around the robot which people may choose to step into or not. When people are in this invisible zone, they expect the robot to hear what they are saying. Likewise, outside this area, people act as if the robot cannot hear them.

   One inconsistency difficulty is when the robot is running speech recognition; loud voices from a distance can cause difficulties. The application was designed so that the robot can only listen to audio and perform speech recognition when a person steps into the proximity zone. However, background noises were also picked up. Therefore, the robot appears inconsistent in listening behaviour. To enable transparency of what the robot is listening to, a transcription could appear on the screen as the person is speaking, as per interacting with the Apple Siri conversational assistant. This would have to be tested to assess if it improved or detracted from the user experience. Fallbacks, such as typing on the screen, should be provided by the robot if the speech cannot be understood, or if the user has a request they do not want to speak out loud.

5. **Privacy Control** Allow users control of their privacy.

   This takes many forms. 1) Firstly, the user has a physical control, in the use of spatial relations, i.e. the user must choose to stand in close proximity to the robot to be identified. 2) Secondly, access control provides the user choices for authentication. In this study, access was provided through the choice of QR code or Face identification. 3) Thirdly, modes of access (speech detection allowing), provide the user with the choice whether to use speech or type on a tablet when interacting. With the amount of background noise sometimes present in the startup hub space, it was challenging for the robot to understand someone talking to it correctly. Speaking loudly to overcome this meant there was also a concern that unwanted bystanders could overhear users. 4) Fourthly, data management, the Pepper hub online system allowed users to control the information stored about them. They could see what information was collected, edit the information as appropriate and delete the information or remove their account if so required.

8.6.3 Process Considerations

Some items for consideration in social robot application discovery and design were learned from this study.

1. Firstly, the pivot in development direction when the necessity of an identity registration system, that would meet privacy legislation, and the extent of design and development that this would require, was understood. The importance of the research team being able to swivel direction easily cannot be overstated. The phased, two stage development process involving a preliminary on-site system test before the main study enabled an agile turn towards the registration system, without wasted effort, yet still was able to ensure user feedback was received on the original service applications proposed.

2. Secondly, the provision of feedback on proposed services for the robot by using and registering with the robot was an unexpected boon to the process of gathering user feedback. It enabled users to have the experience of interacting with the robot, built an understanding of the robot's capabilities and thoroughly immersed users within the intended context of use for their personal data and the proposed services.

3. Thirdly, a small but vital change was additionally made to the process. Real time coding adjustments were made to the robot's behaviour and actions on location before the study began. This participatory co-design and hackathon-style coding approach ensured the best possible robot interactions were in place for the proposed application study. People freely interacted with the robot and provided evaluations on various functionalities which were then adjusted immediately for re-evaluation. The process was iterative, on-the-fly and prevented the need for collecting and later analysing feedback for interaction design adjustments. Developers were able to interact with the critical stakeholders on location, and potential users were able to suggest changes to the robots' behaviours, providing a sense of shared participation and purpose. Suggestions were implemented and re-evaluated. The end result was a set of optimised behaviours and actions for the robot that were grounded in the environment of use and population of proposed users of the robot.

   Moreover, by developing and refining behaviours on site, this also aided understanding as per Nissenbaum's contextual integrity model, where privacy considerations are contextually situated. The physical, social and cultural particularity's of the public space were unconsciously embedded in the user's onsite feedback and evalu-

ations. This ensured privacy-protecting behaviour of the robot and avoided privacy breaching situations such as that described by Chung and Cakmak [70] with their customer feedback gathering robot.

Furthermore, the participatory *"co-design coding"* approach fitted the startup environment and startup culture in which the robot was located. Similar approaches of using hackathon-style development with future users of technology have been undertaken in the HCI community [63] and field customisation has been described as essential to the implementation process for a mobile healthbot in a retirement village [192]. Hence, this method is also confirmed as essential, for implementing a real world social robot application for a humanoid social robot, for a public space.

4. Finally, the process included undertaking a high level yet comprehensive privacy impact and risk assessment based on the Contextual Integrity (CI) framework by Nissenbaum [286]. This ensured compliance with privacy legislation while also ensuring that the information collected in the environment was appropriate and sensitive to the expectations of people in the environment.

The above learnings may be considered relevant for other instances, i.e. any robot registration system required to collect Personally Identifiable Information (PII) for identity authentication. These design considerations may be additionally valuable for any party wishing to implement facial recognition in a similar situation.

8.7 Next Contribution

With this study, the UX-HRI methodology was combined with Privacy-by-Design. This changed the nature of the methodology from straight UX process to more of a privacy-protecting human-centred design methodology. In the final and next contribution, this privacy-protecting, human-centred design methodology for HRI is used to uncover potential applications for innovative social robot technology in an environment where privacy is paramount, a hospital environment.

CHAPTER 9

Social Robots in Healthcare Applications

"The robot's social character extends beyond its physical body, to include multimodal interaction within everyday routines. The robot's social character thus includes its positioning in the space and the arrangement of other actors around it, as well as its interlocutors' talk, prosody, gestures, visual orientation, and facial expressions." Morana Alač, Javier Movellan and Fumihide Tanaka [4, p. 894]

Chapter Summary *Design Study 3: Designing with the UX-HRI framework for socially responsible HRI. Location: Fairfield Public Hospital. My Role: Researcher, Facilitator, Interaction Designer.*

Purpose *Undertake the full process of identifying, designing, developing and implementing a social robot application for a healthcare organisation.*

Methodology *The UX-HRI framework is used to discover potential applications that could improve the experience for staff, patients and visitors to the hospital, in a privacy respectful manner. Additions to the process, of co-design coding, are tested to assess effectiveness.*

Findings *Potential applications are discovered and a multi-lingual, wayfinding application trialled successfully in the reception area of the hospital.*

Contributors *This chapter incorporates the work and findings produced in collaboration with: Jonathan Vitale, Sarita Herse, Syed Ali Raza, Srinivas Madhisetty, Benjamin Johnston, David Kelly, Josephine Chow and Mary-Anne Williams, yet to be published.*

9.1 Implementing Healthcare Applications for Social Robots

This chapter completes the design studies phase regarding trial implementations of social robots in public spaces. In this final design study, attention is directed towards healthcare contributions for social robot technologies. Healthcare facilities are generally either commercial or government institutions, or a combination of both, and provide a prime environment for bringing together and trialling the emergent design principles for social robot applications. Hospitals have been identified in many HRI research studies as places where social robots could add significant value by improving patient care and assisting healthcare staff [41, 166, 392, 399]. Additionally, exploring innovative robotics systems technology for use in hospitals may send favourable signals to critical stakeholders [28]. Hence, healthcare providers are interested to implement social robots in their hospitals.

In this study the design work is undertaken with a local government health district to discover viable use cases and implement a social robot in one of their most culturally diverse hospitals. The health district is seeking ways in which they can use innovative new technologies, such as commercial social robot platforms, to assist both staff and patients. However, deploying real social robot applications in healthcare environments is a major challenge [193]. There is a significant gap between identifying ways in which a social robot might add value in a hospital and implementing a real robot in an actual hospital. Guidance and strategies are required by the health district to ensure social robots deployed in their hospital environments have a positive impact, for both staff and patients.

This study reports the critical steps that were taken to ensure effective external and internal engagement with healthcare providers, allowing the research team to successfully conduct human-centred design research in the hospital environment. Provided here is an extensible template of the process, which can be used by others in the HRI field to accelerate the adoption of social robot technologies in the healthcare space. Additionally, important design implications and challenges to consider in the healthcare environment for social robot application design research are articulated and included in the emergent design principles.

9.2 UX-HRI Social Robot Application Design for Hospitals

With this study the aim is to perform a final iteration of the design methodology in a highly privacy-sensitive, stressful and complex environment of a culturally diverse public hospital. Hospitals can be extremely complex and stressful environments for people: staff, patients and visitors.

Hospital staff may experience stress due to a range of underlying causes (stressors) such as low staff-patient ratios, limited cover/backup for staff who call in sick, and staff having to pick up duties above and beyond their normal workload and/or responsibilities. Stressors may remain problematic for staff over time, as implementing strategies to alleviate stress by addressing the stressors often takes a lengthy time period. These all lead to negative impacts such as reduced productivity and negative health outcomes for staff. [64, 159].

In addition, the complexity of workflow processes within hospitals may exacerbate the stress and anxiety felt by both patients and visitors alike. These individuals may be dealing with a heavy emotional burden, which has been demonstrated to impair cognitive processing and attention at the time of the stress [11, 226]. This may leave patients and visitors feeling overwhelmed, confused, irritated, frustrated, and upset.

Furthermore, hospitals may see a diverse range of individuals from varying cultural backgrounds and languages. Non-native speakers may have additional stress within a hospital environment due to language barriers in communication and understanding of signage, and this may be an additional burden on top of other stress. Bringing these factors together, it is clear that communication and understanding may at times be limited, impaired or strained, for visitors, patients and staff in hospitals. While this is no fault of any party, there is the potential for creating real impact and change if addressed. Reducing the amount of thought and time it takes to access and comprehend information may assist this change.

Introducing new technologies can assist in improving the overall experience at hospitals for staff, patients and visitors alike. Specifically, developing applications that reduce stress, anxiety and negative mental states would be effective for these environments. Social robot technologies, such as humanoid robots, are designed to interact and collaborate with humans in a natural and socially intuitive way [42], ideally in a manner that requires minimal learning and training. For people experiencing a heavy cognitive load, reducing the amount of thought and time it takes to access the information they require

is key. As such, social robots are a useful social technology to deploy in innovative ways to assist people at a hospital. Achieving a successful trial implementation of an innovative technology in a hospital requires a delicate balance, necessitating both provision of a reliable service, while also supporting an unproven experience with a prototype application.

Human-centered design (HCD) approaches, such as design thinking and participatory design, have increasingly (over the time of this PhD project) been outlined in HRI healthcare research as effective methods for determining social robot technology use and interaction behaviours [392, 419]. However these approaches bring a number of challenges when used in healthcare and related fields. For example, healthcare practitioners may be unfamiliar with design research and more comfortable with a different research methodology; medical ethics approvals of design research may take longer than expected; expectations of prototypes vary [154]. Nevertheless, partnering with hospitals brings opportunities unique to the healthcare domain, as hospitals may be thought of as driven by social impact rather than commercial value and necessary community considerations may be drivers for innovation.

With these challenges in mind, the objective of this study is to design, develop, implement and evaluate an application for a Pepper social robot within a hospital setting using the evolving UX-HRI framework for human-centered social robot application design. Building on the previous design study's findings, this study addresses the major research gap in implementing real-world social robot applications. The methodology is further refined and provides a case study for deploying social robots in a real hospital, whilst also advancing the goal of extracting design principles for the class of problems regarding social robot implementation. Similarly to previous work, this study positions the contribution as two-fold. Firstly, this work enables additional validation of the UX-HRI framework for discovering, developing and implementing potential social robot applications. Secondly, it provides detail of a real world, multi-modal novel implementation of a multi-lingual, direction-providing, social robot application.

The application is intended to use currently available technology, without Wizard-of-Oz techniques, and run autonomously without assistance or intervention. The design study continues taking the perspective reported in Research through Design (RtD) from the HCI (Human-Computer Interaction) field, focusing research on the goal of improving society as a whole [430, 431]. Understanding it is not a case of what *could* we make but instead what *should* we make. The intended outcome at the end of this project for the healthcare group is the following:

1. Identification of viable, social robot real-world applications that enhance service provision and user experience for use in hospitals .

2. Identification of potential issues and/or limitations that this new technology can uncover.

3. Discover and mitigate potential risks and ensure the benefits of the technology are attained.

9.2.1 Research Questions

For this final design study I investigate the suitability of the framework to the healthcare environment and concentrate on areas of the methodology that may benefit from further improvement. There are two directions to the research. Firstly, undertaking research in the healthcare environment may involve lengthy ethics approvals and an expected high degree of robustness for prototypes [154]. These issues will provide a robust challenge to the methodology, ensuring that the design assumptions (emergent design principles) and prototype developments are proven sufficient to the task. Secondly, in the previous design study using the methodology at the Sydney Startup Hub (Chapter 8), the team discovered the advantages of participatory prototype development on-site, using real time feedback from users to make immediate adjustments. In this study, it is hoped to extend this *"co-design coding"* part of the process, allowing more time and development hours to be available. It is expected staff and visitors will especially benefit from taking part in this feedback stage and it will assist in improving the usefulness of the application deployed. It may also reduce feelings of anxiety and provide a sense of ownership regarding the robots behaviour.

As such the research questions are the following:

R1 *Does the methodology work in the hospital environment? This includes meeting ethics approvals, adhering to patient confidentiality and privacy constraints, and robustness of service requirements with prototyping.*

R2 *Do the emerging design principles, so far determined as design assumptions, still hold?*

R3 *Is the co-design coding effective in the hospital environment? Can we discern an improvement is possible in the application design from adding this to the process?*

9.2.2 Design Assumptions

The design assumptions for this project are listed here. They include the assumptions from the previous project and new, specific design assumptions for this project, related to this specific context and shown in italics:

1. The social robot applications are designed and developed to function in a professional manner for deployment, using today's technology and capabilities. This means no Wizard-of-Oz techniques, no robot operator controlling and assisting interactions.

2. The application must be stand-alone and able to be used again and again by end-users without intervention by a practitioner or researcher, to reset or restart the application interaction.

3. The application must be able to be used without human guidance. It has to be designed in such a way that end users can intuitively, or with guidance from the robot, make sense of how to use the application.

4. Any sensing or processing must be done as much as possible on-board the robot without the use of auxiliary equipment that would not be present in a real world deployment of the technology.

5. Any Artificial Intelligence systems used must provide a sufficient confidence and accuracy to be able to sensibly guide any decision making required by the robot or by users.

6. Repeatable and consistent functioning is expected at all times that the robot is deployed for use with end-users. There shouldn't be any bugs in the software. Any unexpected malfunctions or lack of capability by the robot will be managed in a graceful degradation or fallback manner.

7. Any visual design will be professional and in a manner that is suitably representative of the organisation. This also includes branding of the robot and tablet screen with a logo and identity.

8. The robot will be designed to behave in a manner that is respectful and polite, as would be expected for any customer-facing employee of the organisation. This includes gesturing, language (inclusive and positive vocabulary) and tone.

9. All functionality will meet privacy legislation requirements. Data management practices will comply with the Australian Privacy Principles.

10. The value the prototype application is intended to provide to service users is real, based on genuine need. There should be a real world benefit to the task the robot is performing.

11. *The robot application must be designed to be inclusive and accessible as possible, with alternative options for a broad spectrum of differing capabilities and needs. The intention is to design for the small percentage of users who have the most needs, thereby easily meeting the needs of the rest of the users.*

12. *The application must not require users to carry a device, download an app to their phone, or any other action that requires more than a simple, physical world interaction, that could be undertaken by a young child or those under a heavy cognitive load.*

13. *Patient confidentiality must not be breached in any way.*

From a healthcare management perspective, a commercially available robotic platform is a preferred technology as it already comes with ISO standards compliance and 'proven' functionality. Hospitals are environments where any introduced technology should not be unreliable, due to the existing stressors that are likely to be impacting people. Furthermore, new technology should be carefully and sensitively managed. In hospital environments, a negative impact can occur if the robot impedes workflow and this can lead to staff resistance to the robot [277]. I firstly look to the hospital environment, then to Human-Centred Design (HCD) approaches in hospitals and finally focus on studies with commercial social robot platforms of humanoid design to understand what can be learned from the research to inform the robot application design with the Pepper robot.

9.2.3 Hospital Environment Considerations

From a recent study surveying 3,000 nurses and midwives working at Australian hospitals it emerged that 71% felt they often had more work than they could do well [377]. Additionally, 32% of the healthcare workers involved in this study were actively considering leaving the profession, resulting in an expected workforce shortfall of 123,000

workers by 2030 [377]. As such, hospital employees often need to concentrate on providing vital tasks for patient's recovery in an efficient way but this is at the expense of other essential social and emotional functions [380], for example, conversation with patients. Social and emotional functions are crucial to promoting social connections between visitors, patients and staff, and aiding patient's recovery. For example, social interactions were demonstrated to boost the survival of patients under chemotherapy by 2% [242]. Emotional support consisting of behaviours such as listening, paying attention to or keeping company with lead to a demonstrated improvement in the quality of life of patients with chronic kidney disease under hemodialysis treatment [355]. Social support, has also been theorized as providing a "buffer" from stress [72]. Changing the situation involves providing nurses with enough time to have those conversations that are essential to patient recovery. Identifying how a social robot application may enable this is an area for further exploration.

While a majority of social robot research in hospitals focuses on assisting carers and practitioners in performing clinical tasks, this study instead chooses to focus on areas such as service provision and user experience in the healthcare environment. Reducing the amount of time consuming, non-health specific tasks that healthcare staff perform may allow them to dedicate more time to spend with patients, providing extra time for the crucial social interactions and conversations it is clear are so vital to patient care. Additionally, reducing the anxiety and stress felt by hospital patients, visitors, and workers, due to the complexity of hospital process and procedures, may have a positive impact on hospital experience and patient recovery times.

9.2.4 Human-Centred Design Approaches in Hospitals

Increasingly, Human-centred design (HCD) approaches such as Design thinking (DT) have been used in healthcare management and innovation [26, 317]. The iterative nature of DT, however, creates a tension between traditional health research standards and HCD [26] due to the more rigorous nature of health ethics approval and the common process of providing a basis for the research with peer-reviewed literature. The challenge of health research ethics approval is one of the many challenges facing designers in healthcare. Design approaches are generally contextual and qualitative, clinical research is often quantitative with randomised controlled trials [154]. Essentially with traditional health research, the problems, processes and metrics are understood and well defined, hence you already know what you are answering before a study begins. Design research, involves discovering and defining what the problems might be, with the related interdependent

processes and metrics involved, before knowing what you are answering.

HCD approaches that have involved implementing changes in healthcare service, have found service changes are successful when a 'soft-start' process is used, based on change-management practice [243]. Even though this study is not deploying a long term solution, any trial that involves staff collaboration will suffer without staff engagement. The 'soft start' process involves creating a shared purpose with front-line staff, letting people tailor solutions and engaging as many people as possible in discussing applications to encourage conversations around the possibilities.

A vast amount of literature exists regarding social robot studies in hospitals. Of the healthcare studies that specifically involve human-centred design, it is participatory design that is a popular choice for social robot application design. For example, Winkle *et al.* [419] describe their use of participatory design within a mutual shaping framework to discover what behaviours would be suitable for a Pepper robot to motivate rehabilitative therapy patients to fulfil their therapy tasks. The study has the concept application for trial already chosen (the "what"), the design process is to determine the "how" of the proposed application to be designed. Participatory design has also been used with older adults with depression, where the participants were involved in a mutual learning process to conceptualise robot designs and applications [229].

Design thinking has also recently appeared in the HCD literature for social robots in hospitals. An exploratory study is provided by van der Putte *et al.* [392] on a Pepper robot deployed in a hospital. The application design approach used was design thinking and the application provided was collecting data from patients. The idea behind this application was to lighten the load of administrative tasks on nurses however it is unclear if this idea was chosen before or after the design thinking process. The robot was placed in a patient's room by the researcher. The study found the acceptability of the robot was lower than they hoped. Additionally, concern was reported that use of the robot would come at the cost of patient care. This feedback adds to other literature [149] supporting the idea that while a nurse has a number of administrative tasks to fulfil with the patient, these tasks also provide an opportunity for the nurse to have situational awareness of the patient and provide social connection and care during their interaction.

The previously mentioned study was taken further by Boumans *et al.* [40] who investigated the effectiveness, efficiency and subjective usability of the Pepper robot collecting Patient Reported Outcome Measures (PROM) using multimodal dialogue. This study reported using a situated cognitive engineering method for the design process, where the patient is brought to the room by the nurse but able to complete the interview

by the robot without any help. Acceptability of this method of interaction was reported as positive and further studies will explore how this information is then communicated to professionals.

This study intends to add to the literature and broaden methodologies available for designing and implementing social robot applications in hospitals. The full study results, from the start to the finish of the UX-HRI process, including all the applicable considerations and constraints, are provided in the following section.

9.3 Methodology

In this study the UX-HRI methodology, as per implemented during the airport study (Design Study 1) and further refined during the Sydney Startup Hub (SSH) study (Design Study 2), is followed. As per the SSH study, the methodology is broken up into two stages to allow for two separate ethics approvals. The first ethics approval involves qualitative research using HCD approaches in a preliminary field study for the particular environment (to discover the 'why' of the research). The second ethics approval involves the prototype application (the 'what') and the proposed experiment with the prototype (the 'how') for study. In agreement with the healthcare group stakeholders, the hospital chosen from the South Western Sydney Local Health District (SWSLHD) for the study is the Fairfield Public Hospital. The Fairfield hospital supports a highly culturally diverse population and is working to improve their services to the community.

9.3.1 Participants

The participants for the Hospital study comprised multiple people. As the study is 'in the wild' in a public setting, participants are determined by their physical presence in the study location at the point in time of interest. These include visitors to the hospital, which includes patients, their families and friends, who are there for the purpose of receiving clinical care or visiting those receiving clinical care. Additionally, contractors, couriers and technicians, who may be on site for a brief period of time at the hospital, may be participants. Furthermore, staff of the hospital are participants. Staff are defined as those who are receiving remuneration for services provided at the hospital, either clinical, administrative or provisioning.

9.3.2 Platform

The robotics platform for the design study is the commercially available Pepper robot. Two Pepper robots from the design team laboratory are used at the hospital. They contain a Question-Answer (QA) application that consists of: a knowledge base of QA pairs for answering generic, open domain questions; the ability to perform mathematical calculations; and the ability to search and return answers from the internet. The knowledge base is continuously updated to improve performance. The robots use this knowledge base, updated for the hospital environment, within the prototype application created.

9.3.3 Procedure

As stated the procedure for this design study follows the two stage process of the evolving UX-HRI methodology.

9.3.3.1 Stage One

Stage One firstly comprises the feasibility and needfinding exercise. Needfinding, as described in Chapter 7, involves studying the environment, the experiences of the people in that environment and identifying any areas that could be enhanced by application of new technology. In this case it includes informal interviews with people (the participants: visitors and staff) at the hospital and general observation. The aim is to have a comprehensive understanding of how the hospital experience could be enhanced for all people with a social robot application in selected venues.

In addition to the needfinding, information is collected regarding the environment and observation of behaviour using physical items specific to the investigated environment. Workflow and environmental factors have been highlighted by Mutlu and Forlizzi [277] as impacting robots successful integration into hospital environments. Suitable locations for the robot to be physically present and areas where workflow may be impeded are determined accordingly. An advantage here of working with a commercial social robot platform is that capability and necessary elements such as size requirements, flooring texture, ramp inclinations etc. are already known. Hence a way of narrowing down suitable locations for the robot to be physically present is to note all of these items at each location. This is conducted first, concurrently with staff interviews. The advantage of this step occurring first is that the amount of areas where patients and visitors are to be interviewed for the needfinding process may be reduced.

The interviews follow the protocol as stipulated in the ethics submission (ETH18-2858). Participants receive a participant information sheet and sign a consent form. Participation in the interviews is voluntary, no identifying information is collected from participants. Interviews are conducted on site and participants are free to walk away at any time. Interviews are semi-structured and ask the following questions:

1. How did you come to the hospital today? What were your feelings and thoughts as you left home and arrived?

2. What positive or negative experiences have you had at this hospital today or on previous occasions?

3. Why was it a good/poor experience? Is there anything you would have changed?

Staff members were also asked about their interactions with visitors, through questions such as the following:

1. What positive or negative experiences have you encountered when dealing with visitors to the hospital?

2. Why was it a good/poor experience. Is there anything you would have changed?

The information collected from the needfinding interviews and observation is collated. Thematic analysis is applied to this qualitative data as per the Design Thinking process. This allows further understanding of the social context and social facilitation effects that may be at play and gives an insight into the opportunities and pain-points that exist in the environment from a human user point of view.

Stage One secondly comprises using the insights on the user pain-points and opportunities from the analysis as a basis for generating ideas and concepts around social robot applications. Team members use post-it notes and follow the rules of *solution agnostic*, *think aloud* and *building on ideas* put forward. The most promising and desirable concepts are voted for and detailed using storyboards. These storyboards are then filtered for feasibility, viability, ethical and community value, until an ideal, end-to-end user experience is established. The two best experiences filtered from the concept applications are considered for development as prototype applications. Experimental measures for testing the success of the prototype application onsite in the hospital are then articulated.

The end of Stage One results in a comprehensive document detailing the observations, insights and opportunities, and proposed concept social robot applications to be

prototyped and tested with potential experiments. This document must be approved by the hospital board and the concept application with proposed experiments passed by ethics before any development or research can commence. While no quantifiably falsifiable hypothesis is presented for this stage, the strength of the design methodology is evaluated via the successful approval of the document by the hospital board and whether it is accepted as is, or with changes.

9.3.3.2 Stage Two

Stage Two only begins with the approval of ethics of the concept applications and proposed experiments from Stage One. Stage Two involves the designing, developing, deploying and trialling the social robot prototype application informed by the exercises of Stage One. The trial includes running the potential experiments for research use.

The design and development process is run concurrently and determines the robot functionality, look, behaviours and actions for the concept application prototype. This involves paper prototyping of touch screens and role play of the robot behaviour in the different scenarios. The minimum viable task that the robot can perform is ascertained and an interaction flow diagram created to aid development.

The process involves breaking down the concept application into smaller, bite-sized tests that can be easily piloted and tested with staff and or users. This allows staff the opportunity to suggest further details of how the application may function to best support them in their role.

Deployment involves further development on-site, with refinement of behaviours and actions. Once the prototype application is ready for the experiment, the research study begins. In this stage, the ability of the design team to improve the prototype application on-site, based on real time user feedback (named in the previous chapter co-design coding), is tested.

Hence the improvement to the design methodology has the following Hypothesis:
H1 *Co-design coding enables an improved application design.*

9.3.4 Measures

The measure of success for Stage One is the acceptance and approval of the document firstly by the Hospital Board and secondly by NSW Health Research, Ethics and Governance for the proposed application and experimentation.

Stage Two involves a number of measures. The actual deployment of the concept application, in a prototype form that is able to successfully function, is the first objective measure. Additionally, staff acceptance of the prototype is measured via online survey as per the Almere model [168], which is based on the well known Unified Theory of Accceptance And Use of Technology (UTAUT) model [394]. However, for visitors returning the survey (post interaction), a shortened indication of technology acceptance was used, due to the finding that most relevant to acceptance is usefulness [96] and the desire to keep the survey as quick as possible to encourage completion.

Secondly, the ability of co-design coding to improve the prototype application and user interaction is measured via improved interaction times, greater or equal technical performance and accuracy, and qualitative feedback in the form of open ended questions.

Thirdly, the ability of the concept application to meet the expected advantages of an improved hospital experience and improvement in staff efficiency is measured via open ended questions and questionnaire.

9.4 Results

9.4.1 Stage One

The type of results typically returned in needfinding interviews and observations are content rich and text heavy. Focusing on the findings relevant to this dissertation, a shortened summary of results which includes the most pertinent, are reported in the following.

9.4.2 Needfinding - Determining Locations

After our initial meetings to agree engagement with the hospital management and approval from both the University Ethics Committee and the Research Ethics and Governance Board for our Stage One needfinding, the first study-related task involved travelling to the hospital to meet with and informally interview staff. The research team paired with hospital staff and dispersed throughout the hospital to learn about the various areas and experiences encountered in each location. At each location, questions about key environmental considerations and constraints were also asked of the staff. These key considerations are listed as follows:

1. Corridor and doorway widths and uses

2. WiFi connectivity
3. Electricity supply
4. Pedestrian flows (observed by research team and advised by staff)
5. Typical audio levels
6. Flooring type (carpet, tiled, linoleum)
7. Room acoustics (e.g. high ceilings)
8. Ramps and walkways
9. Furnishings such as tables, chairs and movable signs
10. Lockable storage rooms where the robot could be stored over night

Additionally, physical items and situations such as available corridor space were also noted. For example, when a patient bed was being wheeled down the corridor and people present in the corridor were walking past, there was less then 30 cm free space.

Approximately 20 staff participants provided feedback. Common themes reported by staff included:

1. The large number of non-English speakers using the hospital and subsequent need for multilingual signage and assistance with translations.
2. The lack of WiFi and electricity supply in the different areas of the hospital.
3. People needing directions and assistance to find a patient or location—Staff members report that patients in the corridors ask them questions such as: *'Where is this ward?'*
4. The lack of communication to families and friends as to when a patient is finished in surgery or moved to a different ward. Visitors do not always know where their loved one is or when they will be allowed to see them after surgery.
5. The reception area does not have a view of how many patients are expected to be visiting clinics in the hospital each day, there is no flow management of visitors, nor corresponding reception area staffing.

A significant finding from the staff interviews was that people commonly asked for directions, especially in the reception area. Due to language and understanding barriers it was much easier for staff to sometimes walk the person to the location they were seeking. While a fantastic service, it removed the staff from other tasks they might have been performing and additionally would take them away from their post, leaving it unattended. Also, it was observed that sometimes people would receive directions, then at a further point within the hospital, again ask for directions from another staff member. Visitors to the hospital also included flower or food delivery people and contractors, who just wanted quick directions.

The research team met to discuss the interview results from the staff feedback. The staff feedback was reviewed to determine the best locations to concentrate visitor and patient interviewing. Locations where visitors may be in a high stress or impaired cognitive situation were marked to be removed from the visitor interview process. The emergency department, intensive care, birthing centre and dementia ward were all removed. Additionally, after comparing staff feedback with environmental constraints, it was apparent that moving a robot around certain corridors and wards would run the risk of the robot getting in the way, possibly causing harm. Hence the places for interviewing were further narrowed down to the few that could feasibly have a robot physically in place. Furthermore, it was agreed the robot would not autonomously navigate the corridors due to the tight width when a hospital bed was being moved in the corridor. Instead, three critical hospital spaces where a social robot may successfully collaborate with staff and assist people were identified: 1) the reception area, 2) the hospital cafe, and 3) the Renal Dialysis Unit (RDU).

9.4.3 Needfinding - Specific Locations

The needfinding in specific locations took place on different dates from the staff interviewing dates.

Interviewing in this stage involved speaking to visitors, patients and additional staff in the three areas selected: Reception area, Cafe and Renal Dialysis Unit. People in the specific location at the time of the research team's visit were asked if they would like to take part and were provided with a participant information sheet regarding the study and participant consent form. People who agreed to be interviewed and gave informed consent to be a participant had to be reassured that researchers weren't collecting feedback to evaluate or criticize the hospital, but rather we were looking for opportunities to offer new services.

9.4.3.1 Renal Dialysis Unit (RDU)

In the Renal Dialysis Unit (RDU), patients either come into the hospital for the morning session or the afternoon session. Two separate trips were made to the unit to ensure both sessions were covered in the interviewing process. The head nurse assisted in pointing out who would be able to answer questions and would be agreeable to be approached for interviewing, as some patients had no English or were not interested in taking part in the study. A total of nine patients were interviewed, three women and six men. Common themes from the needfinding interviews included:

1. The sense of community and feeling of 'family' with the other patients and staff. Patients meet in the waiting room before their session begins to chat and re-connect with each other. One participant described the RDU with: *"Everyone here is like family"*.

2. The lack of WiFi and mobile phone reception making using the phone difficult.

3. The waiting and passing of time—the amount of time that is spent at the ward (three days a week, four–five hours sitting in chair each time, some use books, watching TV, sleeping isn't always possible as it is too noisy).

4. The food provided, likes and dislikes.

5. The difficulty in understanding and following the required diet to keep healthy.

6. The awfulness of the last hour on dialysis and the importance of keeping positive to make sure they had enough energy to get through it.

Observations revealed that although patients said it was too noisy to sleep, the ward itself was very quiet, with the majority of patients appearing to be dozing or watching TV.

9.4.3.2 Cafe

In the Cafe, the majority of people were either staff on a break or visitors to the hospital to visit a family member or friend. Additional people in the location also included close friends or family members waiting for a loved one to come out of surgery or other; staff members having a meeting; patients with appointments to specialist clinics; and family and friends visiting new mothers from the maternity ward. A total of 12 people were

interviewed, two male and 10 female. Common themes from the needfinding interviews included:

1. The cafe staff remember customers and regular clinic patients which makes the participants feel good. A cafe patron reported: *"I find people very friendly in this hospital, especially at the cafe"*.

2. Regular patrons had a preference / sense of ownership for their seating (they could be found in the same place at the same time each week).

3. The communication from the surgery or other clinics was an issue, patrons did not always know how long they would have to wait for a loved one from surgery.

4. WiFi and phone reception issues meant waiting patrons had to keep checking if they had missed a call by going outside the cafe area.

5. There is no real place to sit and wait for loved ones in other areas of the hospital, staff tell visitors to wait in the cafe.

The cafe area was without clocks. A TV is provided in the area of the cafe marked for staff, however it was observed that most patrons did not notice or ignored the sign. There were no options to buy newspapers or magazines to pass the time even though patrons had been advised to go and wait in the cafe.

For visitors, a significant finding was the need for increasing the communication between staff, patients and visitors. A number of people in the hospital were simply waiting for news, of a loved one in surgery, or visiting a clinic, and would have liked different methods to be notified of their completion or loved one's movement. Current methods of sending a text message were not always viable due to the lack of mobile phone reception in the various locations. Additionally, beds may be moved from ward to ward according to hospital requirements without notification being possible.

9.4.3.3 Reception

The reception area is the main entrance to the hospital. It had extremely busy time periods when many people would queue at the reception window for assistance. There were three visitors that were interviewed in this area, one male and two female.

In the Reception area, needfinding interviews and observations included:

1. People asked for directions even though there were signs clearly stating the location they were looking for.
2. People wanted to be able to ask a staff member questions as soon as they arrived, without searching.
3. People would ignore the car-parking payment machine and instead visit the receptionist to pay (only to be re-directed to the machine).
4. There were very few seats to wait in the area.
5. Many different nationalities would speak to the receptionist in a day. A fair proportion of people were non-English speakers and they would present a name on a piece of paper and gesture to get their query across.
6. People were commonly asking for the same directions: The hand clinic, bookings office, maternity ward and cafe.
7. Groups of people would come together into the hospital, for visiting a friend or family member.

The reception area is the first area people arrive at when coming to the hospital. People are visibly seeking direction and reassurance. Those who received assistance from reception appeared relieved.

9.4.4 Forming Insights and Framing Opportunities

Insights into the three locations at the hospital were formed by firstly creating an empathy map for each location based on the interviews and observations conducted. An overall key emotion was also determined, based on the feelings reported by participants in the interviews and also the researcher's experience within the location. The empathy maps outlining the Think, Say, Feel and Do quadrants for the Reception, Cafe and Renal Dialysis Unit can be seen in Figure (9.1).

It was discovered that reception was a point of ambiguity, with people experiencing low level confusion and or anxiety. Many people would seek staff assistance as a first step after arrival, looking for reassurance to assist with their uncertainty dealing with the unfamiliar hospital environment.

The cafe presented itself as a calm waiting area, with people enjoying the social connection and friendliness of the staff. Simultaneously, people felt bored and anxious as

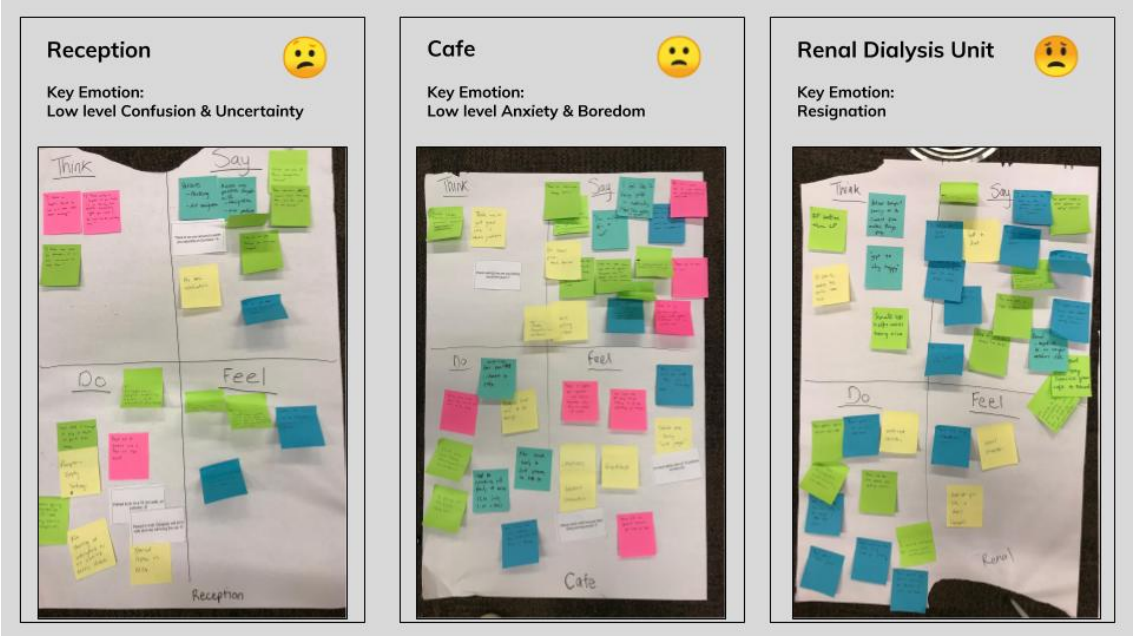


Figure 9.1: Empathy maps for the Reception, Cafe and Renal Dialysis Unit

they waited for news of loved ones or friend, unsure if they had missed a phone message due to poor reception.

Patients in the Renal dialysis unit experience a sense of family with the patients and staff. They were both buoyed by the sense of camaraderie with fellow patients yet also resigned to the dialysis process.

Journey maps were created based on the majority of behaviour observed and reported for each location. In the Reception area, the majority of users requiring assistance were first time visitors to the hospital. Hence the journey map is specifically for these type of visitors. In the Cafe and Renal locations, visitors could be first time or returning.

The activity, the corresponding emotion, and the insight, from each step of the visitor journey were mapped and used to promote discussion. This discussion culminated in creation of *How Might We* statements that would enable addressing the unmet needs of the location via focused brainstorming. The journey maps for each location may be seen in Figures 9.2, 9.3 and 9.4.

9.4.5 Ideation Brainstorming

Following identification of the *How Might We* statements the ideation brainstorming session was held. Hospital staff members were invited to attend this step of the process

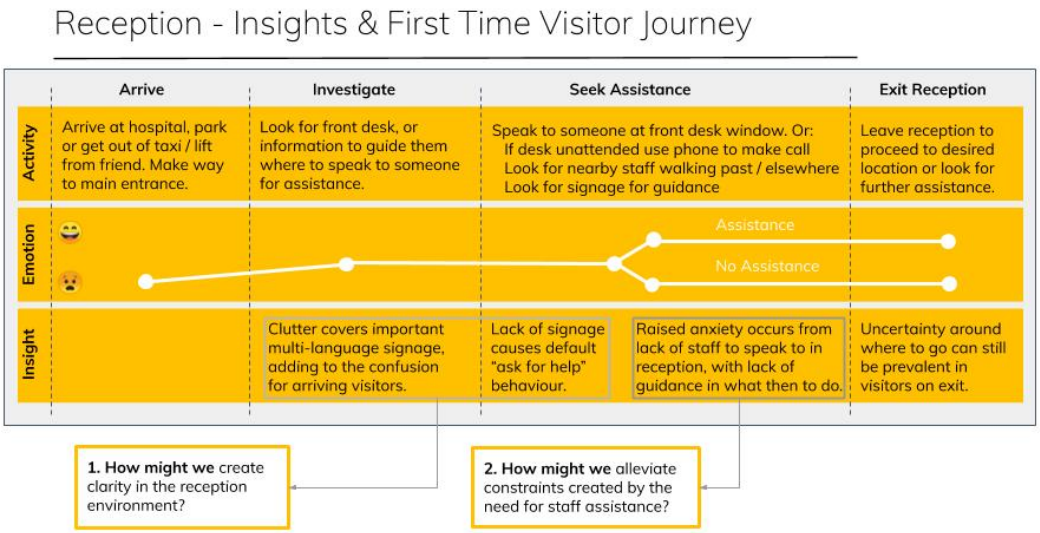


Figure 9.2: Journey map for the Reception

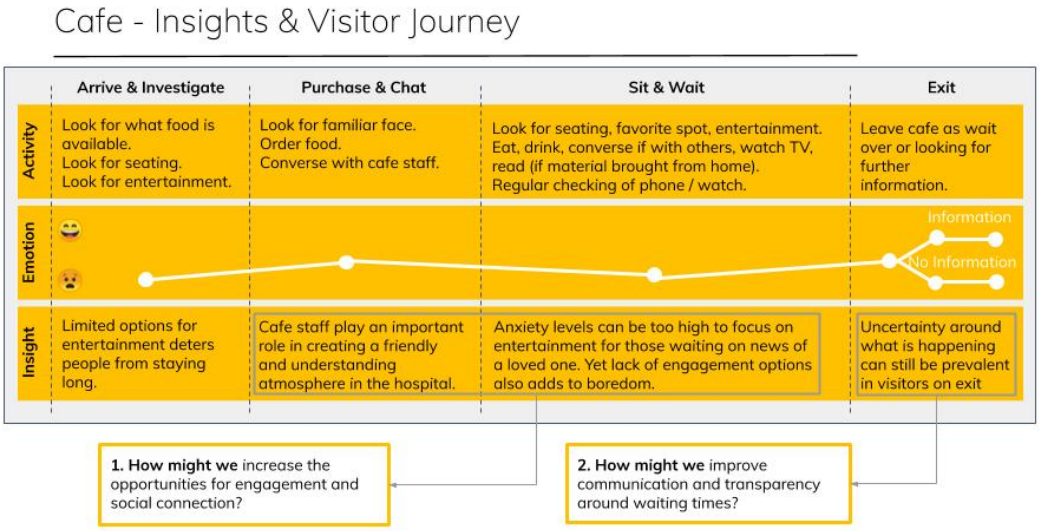


Figure 9.3: Journey map for the Cafe

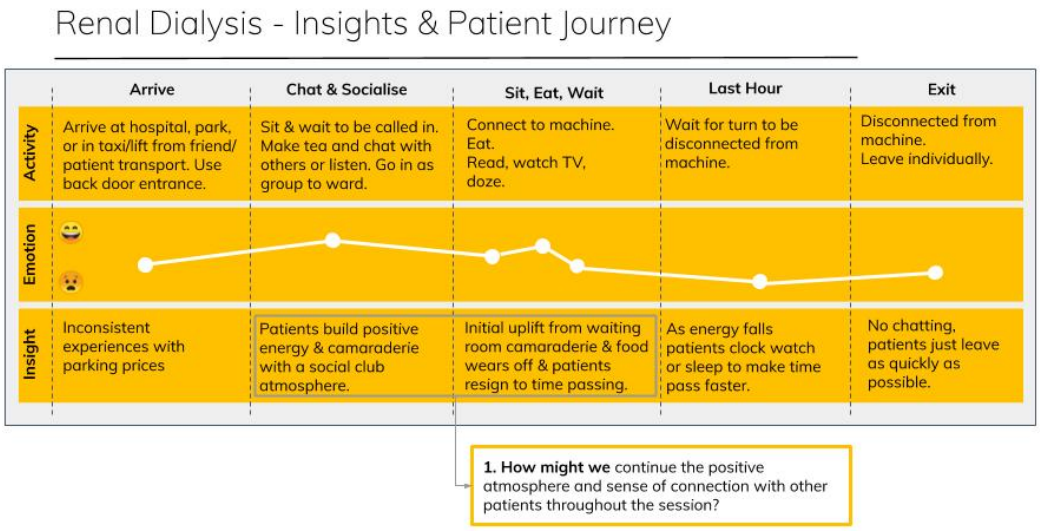


Figure 9.4: Journey map for the Renal Dialysis Unit

however none attended. The *How Might We* statements, generated from the customer pain points and opportunities were used as the basis for idea generation. There were no limitations placed on these initial ideas re feasibility, privacy, ethics, or budget. Themes used to encourage ideas included worst idea possible, most fun idea, most empathetic idea. Ideas were silently written down on Post-its, then voiced without judgement. These could then be built on and blended by team members.

9.4.5.1 How Might We Statements

Reception

1. How might we create clarity in the reception environment?
2. How might we alleviate constraints created by the need for staff assistance?

Cafe

1. How might we increase the opportunities for engagement and social connection?
2. How might we improve communication and transparency around waiting times?

Renal Dialysis Unit

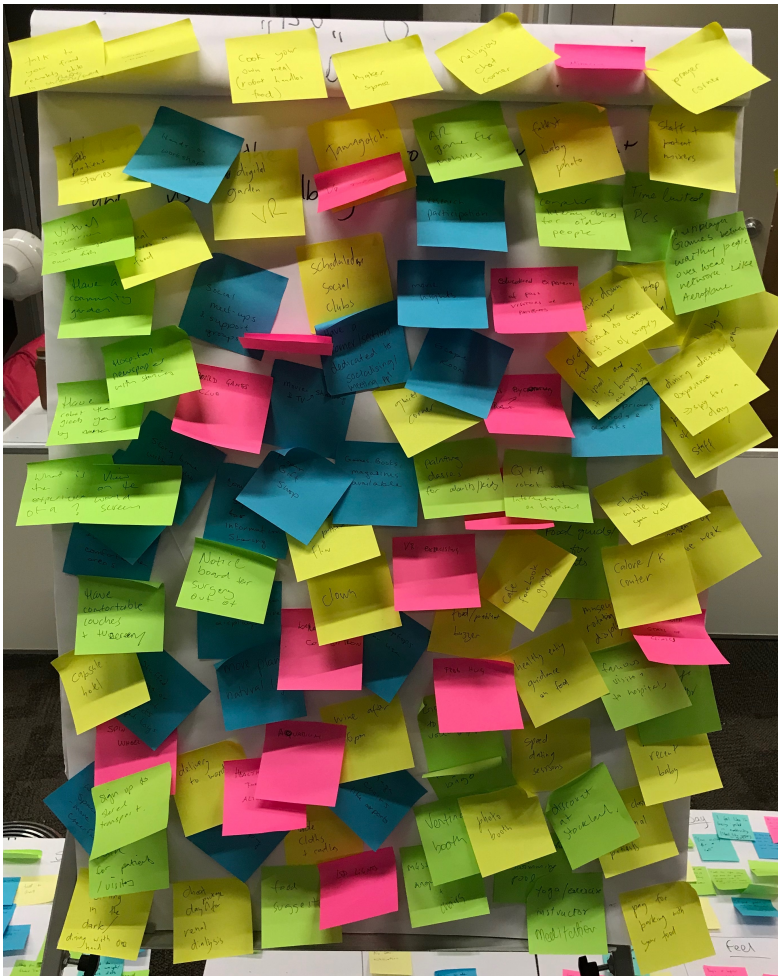


Figure 9.5: Ideation brainstorming

1. How might we continue the positive atmosphere and sense of connection with other patients throughout the session?

More than a 100 ideas were generated for the different locations. Ideas were furthered by asking "How might we *use a social robot to...*" See Figure (9.5) for an example of the idea generation and Figure (9.6) for the grouped ideas.

Ideas were grouped into concept themes, filtered for Feasibility, Viability, Ethical and Community Value, then the most promising voted on by the team.

During this process, key considerations for any potential application were discussed. These included staff collaboration requirements and the impact of involvement on current system processes, technical feasibility and connectivity to existing systems and, most importantly for the hospital environment, ethical considerations such as privacy. A simple privacy assessment, specifically by using the *Threshold Assessment* of the Australian



Figure 9.6: Grouping of ideas into themes

Privacy Impact Assessment (PIA)[1], on potentially viable concepts, were also of value for attaining an initial view of the privacy considerations for the concept application. This involves answering a single question *"Will any personal information be collected, stored, used or disclosed in the use of the application?"*. Privacy discussion additionally involved consideration of the seven types of privacy [120], specifically the concepts of *privacy of the person*, regarding *privacy of behaviour and action* and *privacy of thoughts and feelings*, and the corresponding use of relevant AI technologies. It should be noted that these types of personal privacy are not specifically covered in the Australian Privacy Act. To assist this stage of the process, the tri-fold lens as described in Chapter 6 facilitated promoting the design areas for discussion and ensured further exploration of potential concepts:

1. *Social robot as social agent* - what are the social aspects to consider? Will people feel under observation or unduly anxious because of the robot's presence, and in which situations in the hospital environment would a social robot's assistance not

[1]https://www.oaic.gov.au/privacy/guidance-and-advice/guide-to-undertaking-privacy-impact-assessments/#s1-threshold-assessment

be welcome? Does the robot breach any type of contextual integrity expected within its role?

2. *Social robot as interactive media* - A humanoid social robot with attached tablet can incorporate many communication channels (voice, movement, text, images, video, sms, email, video call). Which of these would be most accessible and could effectively be used? In what situations would they not be appropriate?

3. *Social robot as communication medium* - a social robot can provide an easily accessible interface to surrounding technology and cast to existing technological services or applications. What considerations could be made to make these services more accessible?

Once the final concept applications had been discussed and rigorously assessed, storyboards of the most desirable (according to team members) were created. This allowed visual understanding of how the concept applications would be used, from start to finish. The storyboards can be seen in Figures (9.7), (9.8) and (9.9).

The concept storyboards were narrowed down further, via Impact vs Ease of Implementation, and voting by the research team to the two most desirable, brand new experiences for the hospital environment.

The first concept application was for a Multilingual Reception Robot. Tasks for the application were outlined as follows:

1. Pepper stands in reception and greets customers to the hospital.

2. Pepper assists with general questions and directions.

3. Pepper provides directions in multiple languages.

4. Directions are verbal, on front tablet and with the option of being sent to mobile via SMS or QR code.

The second concept application was for a Solicitous Social Robot. Tasks for the application were outlined as follows:

1. Pepper stands in the waiting area for the renal ward / TV area of cafe.

2. Pepper recognises patients and asks after them[2].

[2]Face recognition is required for this optional item and subject to further discussion regarding information storage.

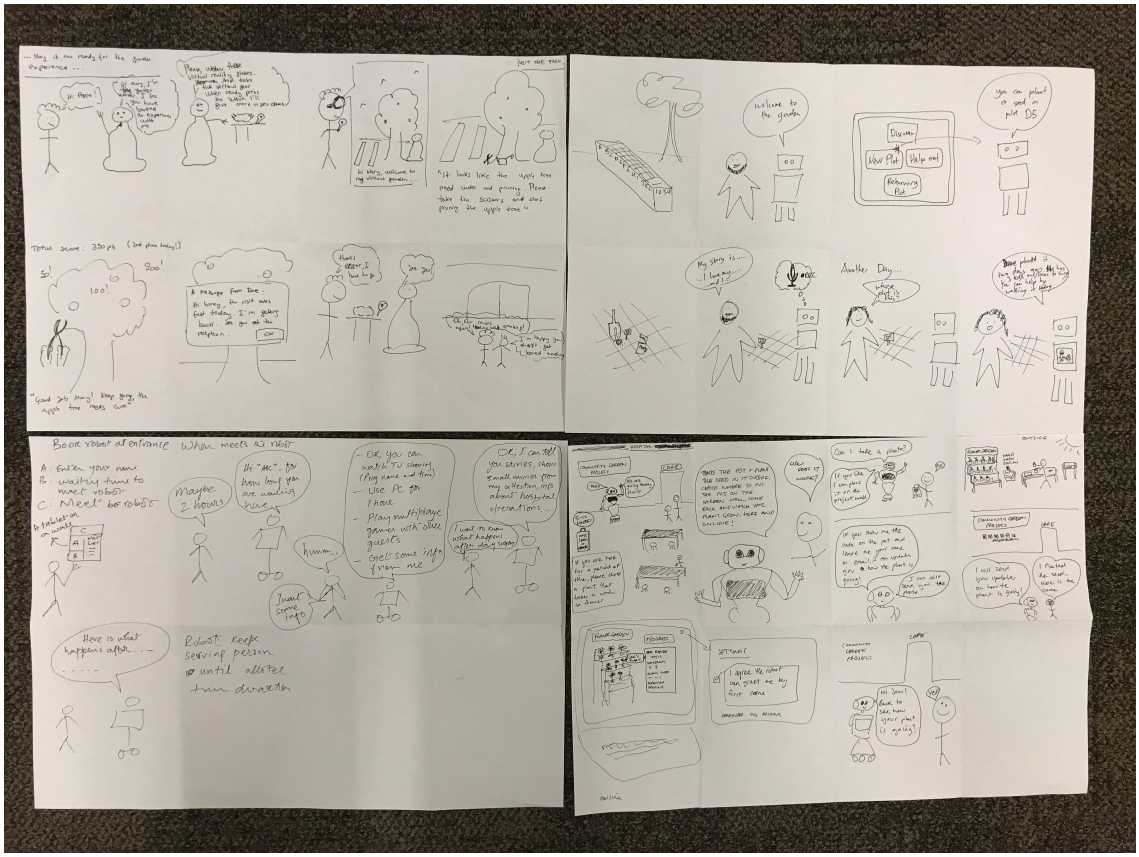


Figure 9.7: Storyboarding of ideas — 1

3. Pepper offers a survey on how they are feeling.
4. Pepper provides question answering, news and information.
5. Pepper acts as a game master for group / individual games.

Additional application features included the use of games to keep people entertained:

1. Patients use their mobile telephone or iPad to enrol in game.
2. Pepper runs bingo, trivia and other parlour games.
3. Pepper keeps a virtual group scoreboard players can view.
4. Furthermore, to combat the lack of WiFi service in the hospital: Pepper offers a Wi-Fi hotspot for services that can enable connection and communication to patients and visitors about hospital information / patients waiting time at any time.

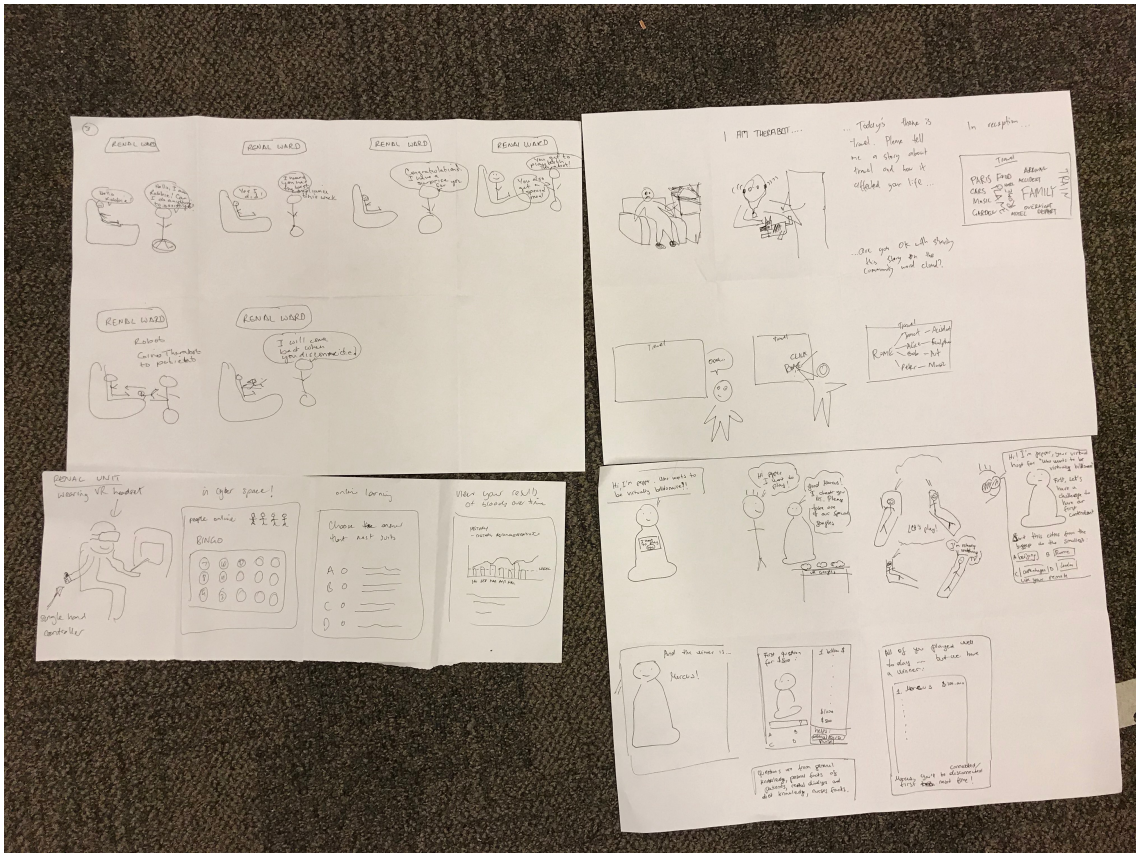


Figure 9.8: Storyboarding of ideas — 2

To move to the next stage of the process, the concept applications required approval by the Hospital Board. In addition, the proposed testing of the applications and the experimental research required approval from NSW Health Research, Ethics and Governance.

The results of the needfinding exercise and the two proposed concept applications, with detail provided from storyboards, were documented and presented to the Hospital Board for approval. Approval for the concepts was granted and the Reception application prototype was agreed to, as the application with which to begin.

9.4.6 Experiment Design

Now that the concept application was decided, the experimental research using the application could begin. Given the importance of ensuring the application was able to assist users of diverse language and abilities, the first research question was:

R1—Study—How might we design an accessible, social robot wayfinding application that is able to assist users who may be non-english speakers, older adults or those

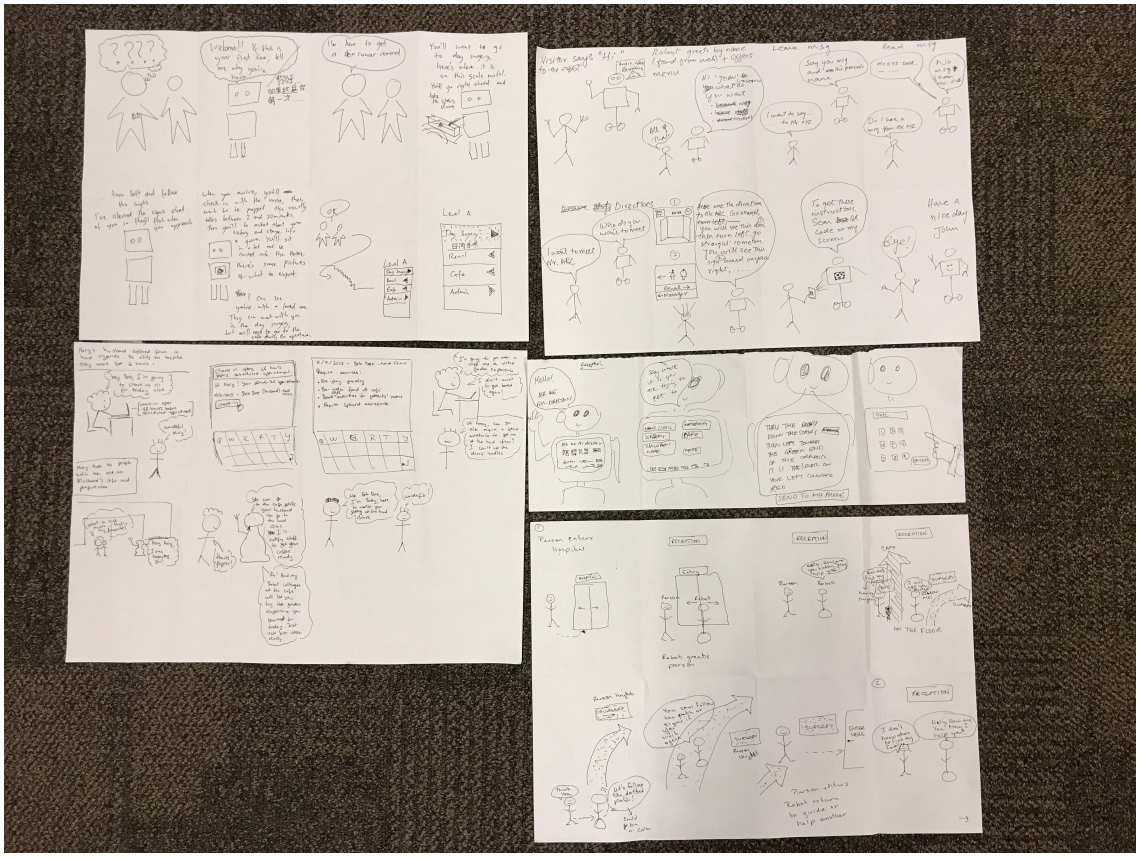


Figure 9.9: Storyboarding of ideas — 3

experiencing varying vision and cognitive abilities.

This is followed by:

R2—Study—Is a multilingual social robot able to understand and handle wayfinding queries and successfully assist people to find their way at the hospital?

In particular, the research team want to understand if:

1. The robot can be easily and intuitively used by both English and non-English speakers;

2. People using the robot can understand the directions given by the robot without getting confused;

3. People using the robot find the interaction positive, enjoyable and useful;

4. Staff at the reception find the introduced technology helpful and able to reduce their everyday working load.

The final part of the Stage One process involved articulating the hypotheses necessary for testing the viability of the proposed concept application. The measures and criteria for success of the hypotheses were determined. The necessary development time to build the minimum viable role for the robot was established. This was enabled by further defining the prototype application functioning. Using the tri-fold lens, additional detail of the application was determined, as a necessity for the ethics approval.

1. *Social robot as social agent*
   Considerations regarding the robot as a social agent included whether or not the robot would learn names and faces. To make social connections, being able to recognise and remember people is vital. However, legal requirements mean that people must explicitly agree to personal information, such as name and biometric templates, being stored about them, and must be given the ability to add, change or delete this information. Hence this would entail some kind of management system and process to do this, as per Design Study 2, Chapter 8. In the hospital environment, it may add unnecessary difficulty to a situation where there is high sensitivity around personal information, while also only aiding returning users. Using the project design assumptions here guided us to the constraints regarding technology use. To provide a system using facial recognition would increase the security risk of a breach of privacy if the system was hacked. Hospitals must provide patient confidentiality in all areas and this is especially the case for well known public figures, such as politicians, who have the right to privacy within the hospital environment. Information such as their presence at the hospital, why they are there or who they are there to visit, their emotional state, who else was with them, their length of stay *etc.*, must all be protected. Privacy protection can be implemented by simply not collecting information that could be used in a breach of security. The implications make it clear that the design assumptions could be compromised, if facial recognition was included.

2. *Social robot as interactive media*
   When considering the robot as interactive media, it was discussed which data would be suitable for the robot to share or reveal. For example, if the robot was to provide communication updates on a loved one's bed location or surgery completion, could this be done in a sensitive and data protective way? Would text, video or voice be used, or a combination? If the robot was to provide telepresence for, or to,

staff, patients and loved ones, could this be done in a privacy preserving manner, without others viewing and overhearing conversations?

3. *Social robot as communication medium*
   Finally, framing the social robot as a communication medium meant assessing how the robot would act and integrate with surrounding technology. For example, a common task in hospital receptions is to call taxis. Allowing the robot to manage this process, booking and updating on a taxi's progress, is a function that could involve the robot casting to the nearby LCD TV screens, mobile phones and integration with the taxi service API's. Would this be technically feasible in a short enough timeframe?

Determining which features could be included allowed an estimation of development time. The prototype application was envisaged to take approximately 3 months to design and build. Initial testing would include the performance and technical ability of the robot in the proposed role and the robot's acceptance and impact on the experience in the Hospital Reception area. The proposed hypotheses for testing the prototype were the following:

H1 The majority of hospital visitors using the robot will correctly use it to receive directions;

H2 A non-negligible proportion of visitors at the hospital will use the robot in a language different from English;

H3 Visitors using the robot will find the interaction easy, intuitive and enjoyable;

H4 Visitors seeking directions from the robot will find the directions given by the robot clear and useful;

H5 Staff will have a positive perception toward the introduction of the robot at the reception and understand its value.

The intended concept application, hypotheses to test and corresponding measures were then submitted to NSW Health Research, Ethics and Governance Review Board for approval to test in the Hospital. When the approval was granted (REGIS 2019/ETH13615),

Stage Two of the process could officially begin. The back and forth of the hospital ethics approval for trialling of a prototype application took approximately 12 months. Further design assumptions were added during this time to the project for the build of the application:

1. Further and beyond meeting privacy legislation, all interactions with the robot must avoid breaching any form of patient confidentiality or privacy. This means specifically that there should be no use of AI technologies using sensitive information, e.g. Emotion Recognition (privacy of thoughts and feelings), Face Recognition (privacy of person, data and image), Voice/Speaker Recognition [3] (privacy of person), or retaining of sensitive information should it be asked. Furthermore, no connection to, or tracking of, personal hardware (mobile phone) MAC address, WiFi or Bluetooth, is to be used. There should be no profiling of any individual.

2. The security of the application must be assured, to the extent that there is no information collected that could in any way comprise confidentiality should the system be hacked.

The challenges encountered during this ethics approval process are documented in the Reflections section of this chapter.

9.4.7 Stage Two

Stage Two began with the approval being received from NSW Health Research, Ethics and Governance. The Stage Two process firstly involved the design and development of the concept application into a minimum viable prototype, then the onsite deployment and trialling of the prototype with potential experiments. The three parts to the design and development stages were run concurrently. The same tri-fold lens from Stage One, see Figure 9.10 and with additional privacy considerations see Figure 9.11, was again applied in this design and development stage so as to ensure not to miss any possibilities of how the robot could provide the application required.

To address the first lens, the robot was designed to only engage with the people who specifically came across to interact with the robot. This was to avoid hospital visitors feeling they were required or pressured to interact with the robot. The robot would stay in one place within the reception area and avoid circulating around the room. The previous

[3] It should be noted the difference here between speech recognition (speech -> text) versus speaker recognition (speech -> speaker identity)

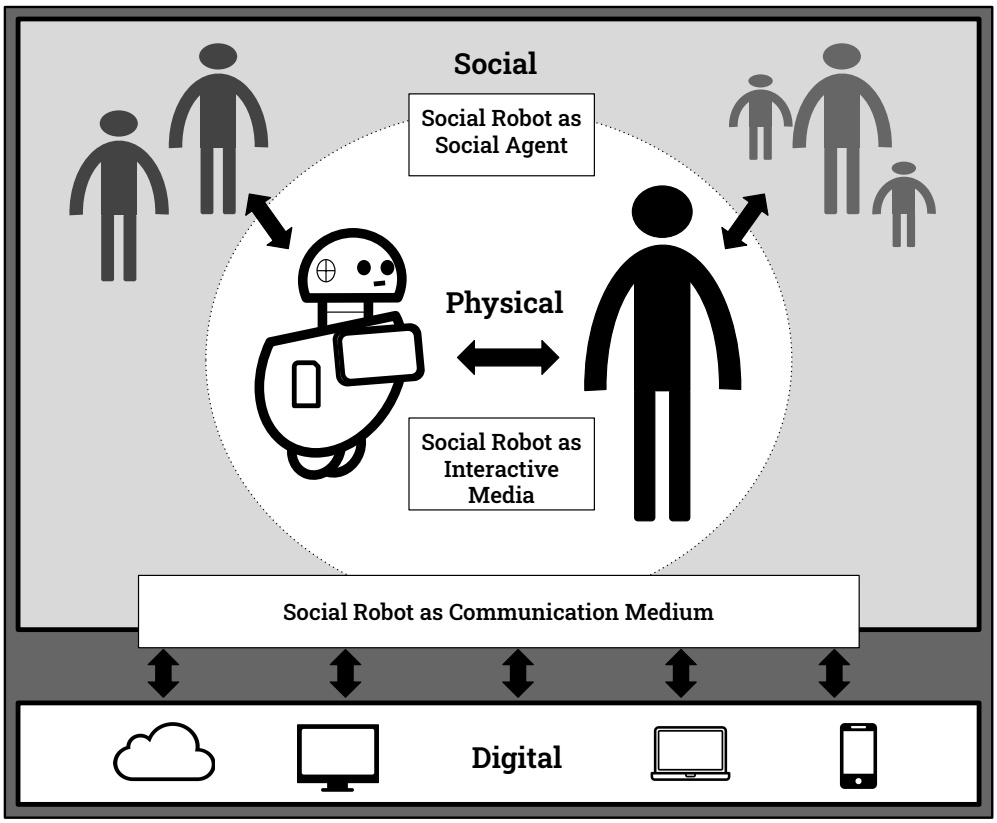


Figure 9.10: Tri-fold lens for viewing possible applications

study from Chapter 4 found a passively engaging robot to be effective in engagement. Additionally, to communicate the protection of privacy, the robot would need to exhibit consistency of privacy-protective behaviour i.e. not responding to returning visitors (recognising people) and not reacting to emotional behaviour. The analogy that found applicability here is a fast food restaurant chain's customer service. The customer service is always polite and respectful regardless of appearance, emotional state, number of visits or behaviour, yet also adaptive to different capabilities. This leads to the second consideration regarding interactive media.

Using the second lens, the consideration of the many communication channels that the robot could use, led to the concept of using visual imagery, such as images and video, to assist wayfinding. This would meet the demands of the largely multicultural population visiting the hospital as a way of providing directions that were language

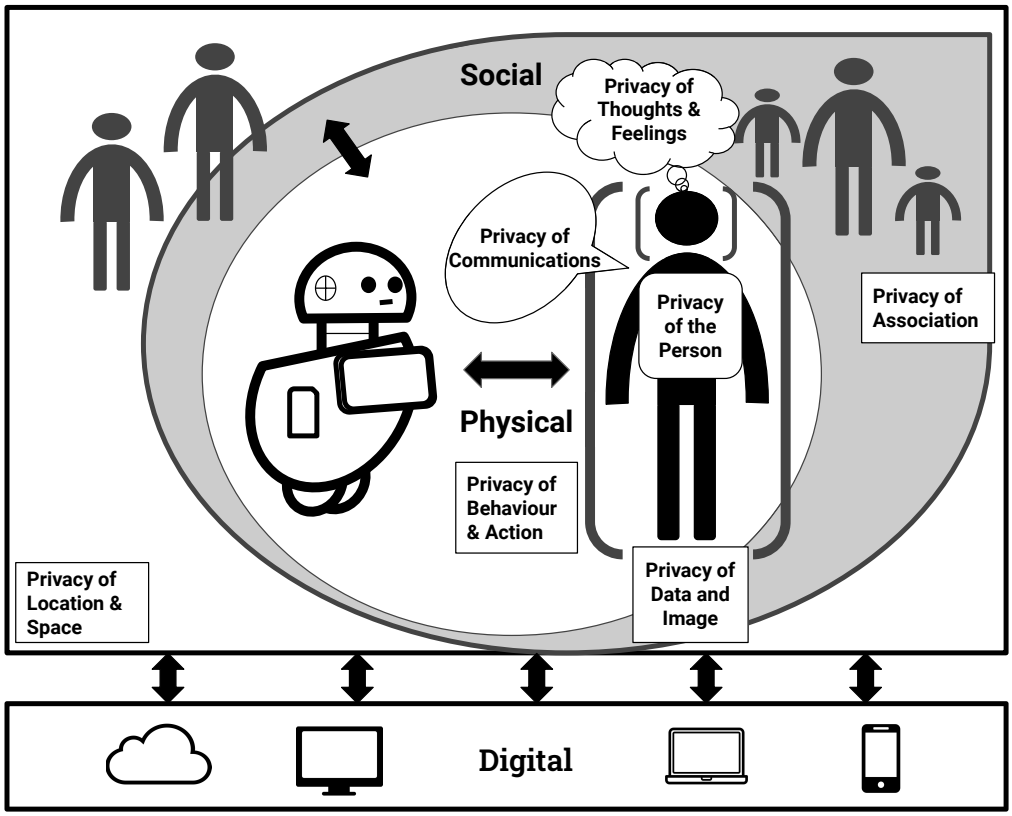


Figure 9.11: Tri-fold lens with the 7 types of privacy [120] in HRI

agnostic. Since it was not possible to physically show the way to the destination, showing the way via video was the closest equivalent. Sped-up video was trialled in a simple A/B test (voice / voice plus video) with the research team on the university grounds, and found to be a potentially workable method of providing language agnostic directions. A path to the desired location of choice was filmed and combined with voiceover and gestures by the robot to match with landmarks displayed in the video. A review of the literature revealed only limited studies in video-wayfinding [65] proving the application a novel approach for social robots. Video was considered beneficial as video imagery can be independent to the spoken word/language. This meant visitors of any language could view the path to their destination. Additionally, for visitors or patients coping with cognitive impairments, from stress or other difficulties, the simplicity of watching a video to see the path they have to take may be less effort then trying to remember a number of instructions [424]. Furthermore, by ending the video with a clear image showing the final destination it assists those people who were not sure if they had navigated to their

desired destination. As such, the robot application was designed and built to provide multilingual, verbal directions and gestures that were synchronised to the appropriate landmarks shown within the video. For people with visual impairment, being able to ask for directions by voice and receive verbal directions ensured they too received assistance.

Finally, for the third lens, it was decided that the robot would cast video to the large touchscreen, that was placed beside the robot to display the video for the path to each destination. Two reasons are given for this decision:

1. *Screen size*.
   The tablet screen on Pepper is quite small, so for those people with deteriorating eyesight it alleviated the difficulty of looking at a small image. Furthermore, for family groups commonly requiring directions to the maternity ward, the larger screen meant each person could easily view the video. Finally, for taller people, it alleviated the necessity of having to bend down to see the robot screen, potentially causing discomfort.

2. *Alternative modality*.
   The large touchscreen provided an alternative method and fallback by which users could start interacting with the robot, if the robot did not detect they were in front. This ensured visitors could use their preferred modality, either using verbal communication with the robot or communicating via touchscreen, to see the video path to their desired destination.

To assess the viability of using video, design testing with an iPad was undertaken to understand if people were able to follow the directions given via video. The paths to a small sample of popular destinations within the hospital were filmed and verbal directions were given to each landmark along the path, by a team member. The landmarks were determined from interviews with staff who commonly had to provide directions. These videos were then tested with staff who provided instantaneous feedback. Importantly, the extent to which the video could be sped up was confirmed.

Finally, the application design was further assessed for privacy impacts and risks, and adherence to contextual integrity, ensuring there was no negative impact on privacy or UX.

9.4.8 Personality and Identity design

Personality plays a vital role in the experience with social robots [230]. In this Hospital environment the task at hand is one which requires gentle efficiency. Visitors may not be in the mood for jokes or flippancy due to underlying stress. The personality features for the robot were identified according to the role the robot was intended to perform, observations of staff and visitor interactions and the project assumptions. Additional literature investigation revealed polite behaviour in speech and gestures is an important factor in healthcare for social robots, and direct speech with polite gestures increases patient compliance to advice [235].

The Who, What and How categories defined the personality principles:

- **Who:** Kindly, Gentle, Helpful, Fast, Efficient, Considerate.
- **What:** Polite, respectful, accurate service. Augment, not replace, the receptionist role.
- **How:** Answer quickly, directly and accurately with polite gestures. Articulate that needs can be met, either by robot/screen or receptionist.

The robot application was built specifically to assist with providing multilingual directions to various locations around the hospital to visitors. Visitors may be feeling stress or anxiety due to their need to be in the hospital environment (either as an intended patient or visitor to a patient). However, in providing this role the robot would also encounter visitors who would be eager to engage with the robot and test out its skills. Therefore, attention was paid to the responses the robot would provide to various open domain questions. Due to the necessity of ensuring complete privacy for patients, the robot did not use the full knowledge base system which would have allowed searching the internet for answers to trivia style questions (or answering mathematical questions), nor patient name enquiries, to ensure no privacy breaches would occur. Instead visitors were re-directed to the Reception staff for their enquiries.

The robot tablet was visually designed to appear to be wearing a NSW Health Staff uniform and badge and stickers were placed on the robot body to indicate the ownership by University of Technology Sydney. The robot was named according to the appearance of the stickers: “Bubbles”.

9.4.9 Design of Interaction Behaviour

Firstly, due to the conclusion that the robot was unable to navigate the hospital corridors, as found from the needfinding process, a fixed position was discussed and agreed with staff, for the robot to inhabit within the Reception area of the hospital. The robot would be situated at the next window to the receptionist, so visitors would be able to move across to the robot easily. See Figure 9.15 for an understanding of the location. This fixed positioning bound the gestures and behaviours to match the constraints of the chosen position. It also allowed heuristics, such as interaction distances to be easily determined and clearly allowed people to walk past without fear of possible interaction with, or surveillance from, the robot. Secondly, technical constraints meant only 5 languages of the area were able to be provided by the robot. These were English, Arabic, Vietnamese, Chinese and Italian. The default language for the robot was English and visitors would have to choose from the other languages. To allow an easy way for visitors to see and choose a different language, the large touchscreen was placed to the side of the robot at shoulder height, displaying the languages available. When visitors chose a language from the touchscreen, Pepper would change to greeting in the chosen language and then asking for where they needed to go.

People could speak their question to the robot and then receive the appropriate directions at the same time as the screen would display the video to the location. Essential information, regarding commonly asked for locations, had been provided by staff and documented. The pathways to each of these locations from reception were filmed and combined with the updated knowledge base containing the voice directions. The robot was programmed to speak at the appropriate moment within the displayed video. For example, as the video displayed turning down the corridor, the robot would gesture and say “Turn left and continue down the corridor”.

9.4.10 Prototype and Build

The initial prototype application was built in a modular fashion, separating the various functionalities from the main process (state machine architecture). Once all functionalities were complete (tablet screen, multi screen connection, dashboard, speech recognition, face detection), the robot was brought to the hospital, ready for further refinement and testing. As per the process, the build involved multiple iterations of user testing with micro-interactions with the research team and also interested staff and visitors to ensure appropriate interactions and functionality for the application. No data was collected



Figure 9.12: Pepper's tablet, displaying the speech heard when in listening mode.

during this time.

The on-site development matched and tweaked the robot functionality to the conditions within the Reception environment. For example the background noise and acoustics for speech detection, the lighting for face detection, the audio level of the robot's voice, the area at which the robot would face when not interacting, the angle of the head when responding to a greeting. The knowledge base was continually updated throughout this time with staff suggestions and visitor feedback.

Furthermore, in the previous design study, Chapter 8, it had been observed that a 'Siri-like', real-time display, on the robot's tablet, of the speech heard by the robot may help people confirm if the robot had heard them correctly. This was implemented in the prototype and the speed at which the words were displayed on the screen was determined during the testing. If the words displayed too slow, the interaction had already moved on, if the words displayed too fast, people would correct themselves as they watched it, confusing the system. The right speed was quickly determined after a few interactions. See Figure 9.12 for an example of the animated tablet display.

Two robots were taken to the onsite location. One was used for interacting with participants, the other was used to test and update with changes for the next iteration of the prototype application. To assist and smooth the onsite coding process, a web based dashboard was created for updating the robot knowledge base, grammar, hospital locations, and sentences. Additionally it provided clear visibility of the accuracy of

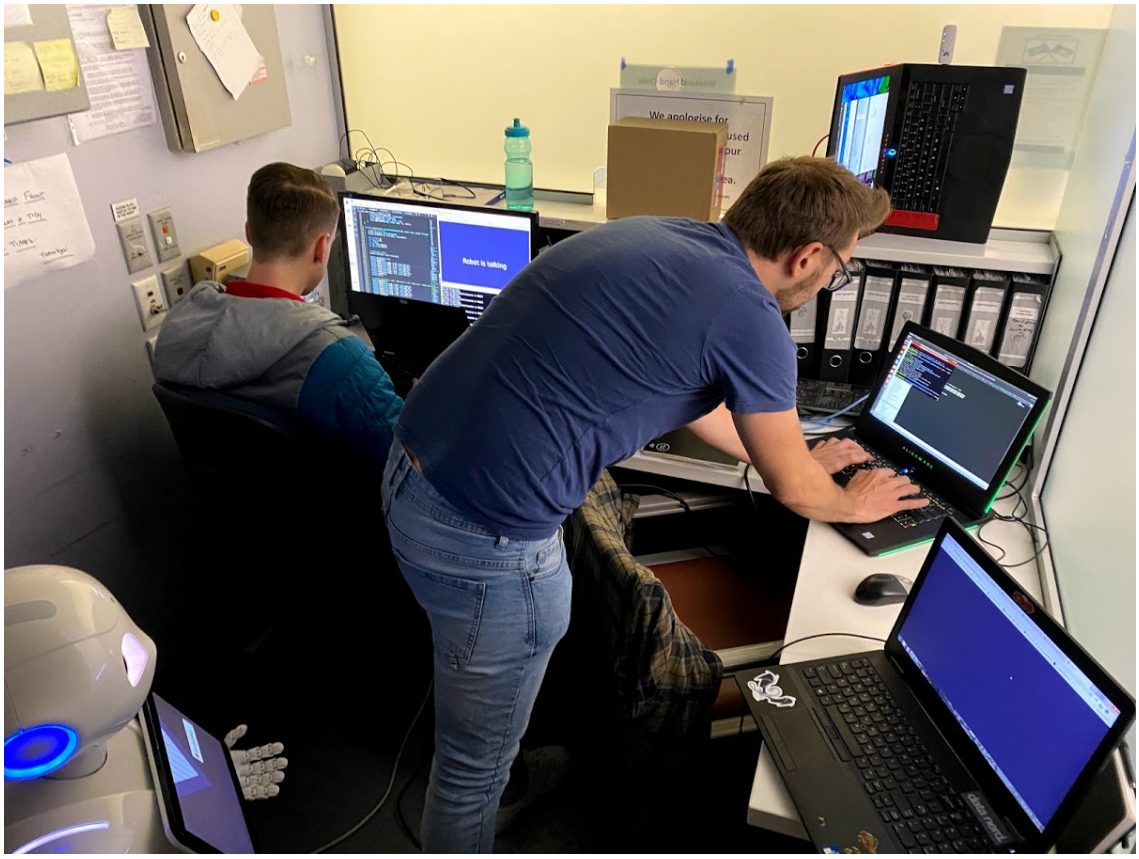


Figure 9.13: Coding room for onsite co-design coding process

the robots speech recognition, see Figure 9.14 for an example. Two full days of onsite tweaking and rapid application development occurred as part of the onsite co-design coding process, followed by two full test iterations of the prototype application. The onsite coding took part in a small room located just next to reception. See Figure (9.13). This provided a place to install the WiFi router for the robot and desk space for developers to undertake coding changes. The room was lockable and all assets were able to be safely secured at night.

9.4.11 Measure and Learn

The robot was deployed onsite at the hospital to test the hypotheses identified at the end of Stage One. Following is a description of the onsite study undertaken for this Measure and Learn step.

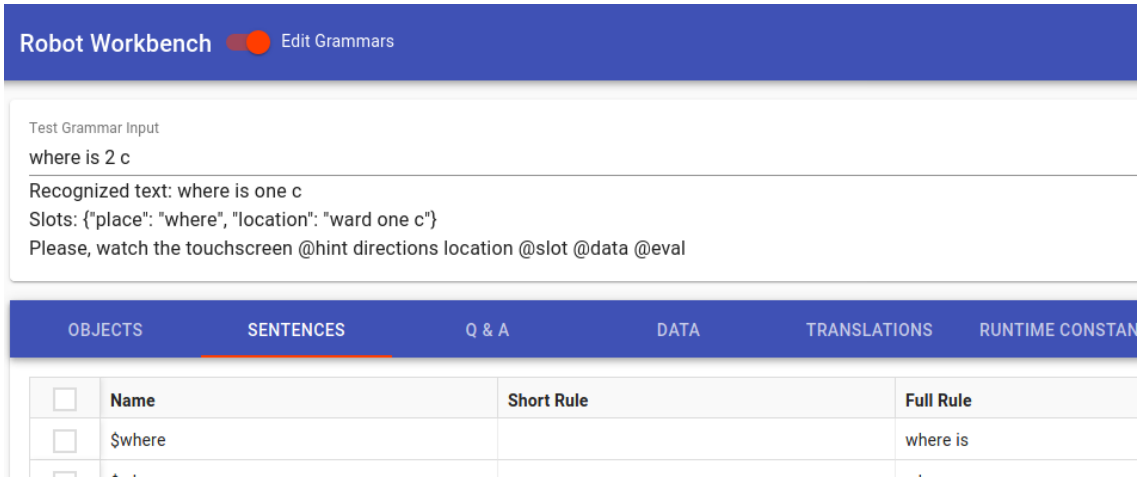


Figure 9.14: Web based dashboard on iPad showing incorrect recognition

9.4.11.1 Study Design for Multilingual Wayfinding Robot

As reported above, the study was situated in the reception area of the Fairfield Public Hospital, part of the South Western Sydney Local Health District (SWSLHD). Pepper, the humanoid social robot was tasked with providing directions in English, Arabic, Vietnamese, Chinese and Italian, to visitors to the hospital. The directions were communicated verbally by the robot and timed to match a sped-up video of the path to the destination, shown on a large touch screen next to the robot. The robot was clearly visible to anyone entering reception and was placed in the position of the second window for reception. Beside and around the robot was signage indicating the research study and the implicit consent to the study by interacting with the robot. A large banner advertising the research study also included the logo of the university conducting the research, see Figure 9.15. Behind the robot was a table containing the Participant Information Sheets and Post Interaction survey. Interactions with the robot were monitored by the researchers from seats at the side of the reception area. The robot was placed in the reception area for a total of 7 business days. The first two days were spent testing and adapting the application, refining the robot's behaviour to the environment with on-location users' feedback from both staff and visitors. No data or annotations were collected during this time. The study was then run for 5 days from 8am till 2pm each day, and consisted of two iterations of the prototype application, trialled for 2.5 days each. Collection of interaction data and annotations from observations, post-interaction questionnaires and collection of 'before' and 'during study' staff questionnaires were completed.



Figure 9.15: Fairfield Hospital Reception

9.4.11.2 Participants

Visitors, patients and staff in the hospital reception area were free to interact with the robot. The robot camera was able to detect when a person was standing in front of the robot at a distance of 1.2m, at which point the robot would greet the person. It would then provide an invitation to select a language from the touchscreen and to ask for directions. Users were free to leave at any time by walking away from the robot. The robot was completely autonomous and participants interacted with the robot without being given any instructions by the researchers. The consent to take part in the study was implicitly given by the participant when they interacted with the robot and this consent procedure was posted in various languages on the wall beside the robot. The study protocol was approved by the Ethics Committee of the University of Technology Sydney and the NSW Health Research, Ethics and Governance Board. Participants were able to ask any question of the robot and the robot had a knowledge base of Question Answer (QA) pairs that it could use to reply. These QA pairs included general information, information regarding the hospital, its surrounds and facilities, and common questions asked of a social robot, e.g. “What is your name?”. When a participant asked specifically

for directions the robot used a distinct directions knowledge base that combined video and text. The robot would direct the person to watch the wayfinding video on the large touchscreen while correspondingly providing verbal directions to the location. All users who began an interaction with the robot by either speaking or touching the touchscreen were noted. An interaction participant was included if the participant selected a language, chose from the touchscreen or spoke to the robot and remained while the robot responded. Criteria list exclusions were children, researchers listed in team, the robot crashing before or during interaction and people testing over and over at different times (only one log of interactions would be counted). Participants were approached after their interaction by the researchers and invited to complete a post interaction survey, for which they could receive a $10 supermarket voucher on return. Staff were invited to interact with the robot and take part in an online survey before, during and after the robot's deployment. The study was wrapped up early due to COVID-19 concerns at the hospital. The staff surveys for after deployment, and follow up interviews, were not conducted.

9.4.11.3 Measures

Researchers observed and annotated whether a participant was a staff member, visitor or unknown user type. Additionally, researchers noted user behaviour with the robot, if there was any confusion or reluctance. Researchers noted if the query was correctly understood and answered by the robot. It was also noted if users left the interaction early, appeared not to understand the directions (by then going and asking reception), difficulties encountered, and any facilitation by either staff or researchers. Due to possible health and sensitivity issues in the hospital environment, facilitation with directions was considered more important then study data, as people may be in a sensitive or impaired state and unable to cope with uncertainty or novelty.

On the robot was logged the language used to query the robot, the first modality of the interaction (speech or screen), the query asked by the participant, the interaction duration and choices, and the number of interactions undertaken by the participant in the one session. At the end of each interaction the robot asked for feedback.

In Iteration 1 the robot asked on three separate screens:

1. Was I able to assist you today?
2. Were my directions clear? (only asked if the question was to ask for directions)
3. Did you enjoy my service?

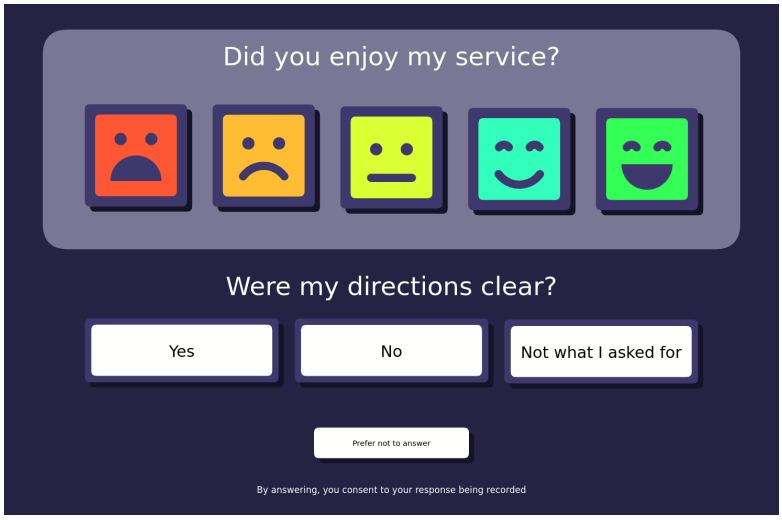


Figure 9.16: Emoticons to rate service

In Iteration 2 the robot asked on the one screen:

1. Did you enjoy my service?

2. Were my directions clear? (only asked if the question was to ask for directions)

The question was asked with a five point rating scale of Emoji faces, see Figure (9.16)). Participants were also invited to complete a post interaction survey, for which a number for their interaction session was provided to the researcher by the robot.

9.4.11.4 Study Results

A total of 196 people interacted with the robot of which 43 were excluded as interaction participants due to the inclusion criteria. A total of 39 participants returned post interaction surveys. Participants who interacted with the robot were comprised of staff (N=62), visitors (N=80) and unknowns (N=11), see Figure (9.17). Participants were counted as staff if they were wearing a uniform for the hospital or a badge as a staff member. Unknowns were those which were missed being annotated as either visitor or staff by the researcher.

The majority of queries asked of the robot were for directions. However there was a small percentage of non-contextual queries, see Table 9.1. The majority of queries were asked by participants speaking English (N=125), as opposed to languages other than English (N=28), see Figure 9.18. Note: the Figure shows the query language of an included participant. A further small number of interactions were in languages other

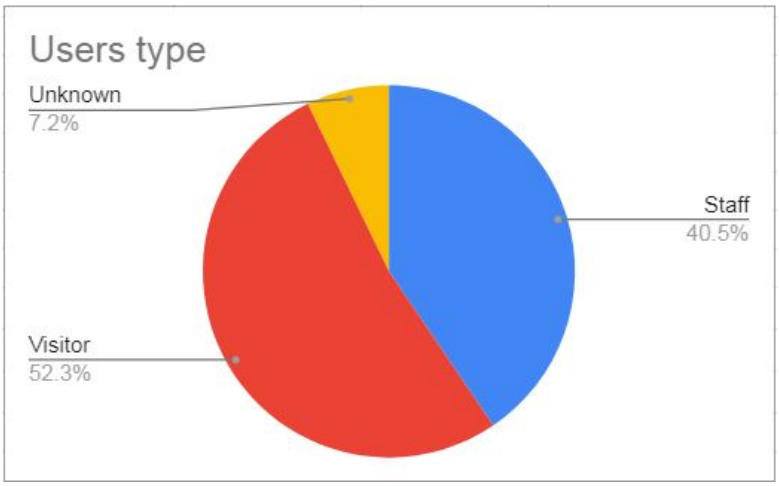


Figure 9.17: User type

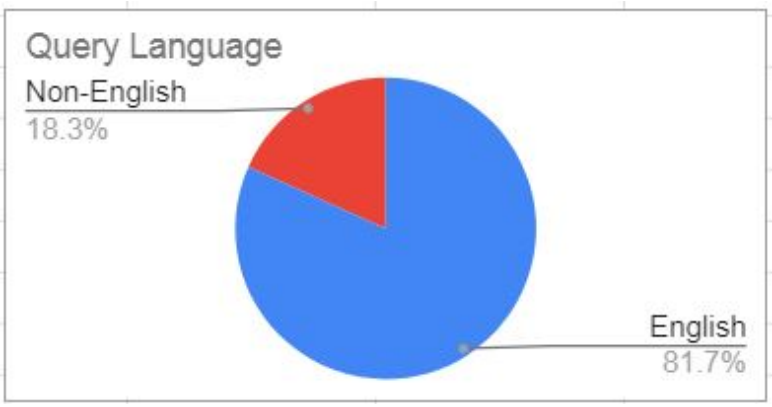


Figure 9.18: Query language

than English for which the robot was not programmed and did not meet the inclusion criteria. Staff, on average, interacted with the robot two times in a session, to 'test' the robot, and visitors once, see Table 9.2.

The accuracy of the system for answering (first interaction) can be seen in Table 9.3 and Table 9.4. The modality of choice for the first interaction can also be seen in Table 9.5 (Visitors) and Table 9.6 (Staff).

In Iteration 1, the hospital locations touchscreen view was displayed only after the robot had verbally responded, delaying the view of the locations to the participant. Iteration 2 of the prototype displayed the locations of the hospital on the touchscreen immediately after a participant had touched the screen to begin an interaction. Additionally, Iteration 2 included the turning of the robot's head to look at the touchscreen when displaying the video path to location and when selecting from the touchscreen. This

Table 9.1: Interaction type by user type

	% Staff	% Visitor	% Unknown	%Overall
Only direction queries	82.26	70	81.82	75.82
Only other contextual queries (excluding directions)	0	8.75	0	4.58
Directions and other contextual queries	6.45	2.5	0	3.92
Only non contextual queries	3.23	12.5	9.09	8.5
Contextual and non-contextual queries	8.06	6.25	9.09	7.19

Table 9.2: Average number of interactions per user by user type

	Average Interactions
Staff	2.15
Visitor	1.56
Unknown	2

Table 9.3: Accuracy in providing correct directions for the first location asked (first interaction accuracy)

	Iteration 1			Iteration 2		
	hits	**misses**	**accuracy%**	**hits**	**misses**	**accuracy%**
Staff	19	7	73.08	24	10	70.59
Visitor	17	7	70.83	31	8	79.49
Unknown	3	1	75	6	0	100
Overall	39	15	72.22	61	18	77.22

non-verbal action was implemented to communicate to the user to look at the screen. People were asked to rate the experience with the robot at the end of their interaction however many participants simply walked away after receiving their directions from the robot. In Iteration 1, a limited number of ratings for first interactions were received (25 responses). In Iteration 2, the rating screen was redesigned to reduce screen touches required and to make the feedback process quicker, and it was shown earlier in the interaction flow to participants. The question “Was I able to assist you today?” was also removed as this information was considered extraneous, it was effectively covered already by the researcher annotations and the user interaction. Service ratings received increased slightly in quantity (33 responses). The average ratings received from Staff and Visitors can be seen in Table (9.7), sorted by correct and incorrect query answers given by the robot, for the two iterations. Only one rating for a first interaction was

Table 9.4: Overall accuracy in providing correct directions for the first location asked (first interaction accuracy)

	Overall		
	hits	**misses**	**accuracy%**
Staff	43	17	71.67
Visitor	48	15	76.19
Unknown	9	1	90
Overall	100	33	75.19

Table 9.5: First modality of use for visitors asking contextual questions (directions or hospital related enquiries)

	Visitor			
	Using Speech		**Using Screen**	
	Iteration 1	**Iteration 2**	**Iteration 1**	**Iteration 2**
English	21	22	0	9
Non-English (overall)	8	8	0	2
Totals	**29**	**30**	**0**	**11**

Table 9.6: First modality of use for staff asking contextual questions (directions or hospital related enquiries)

	Staff			
	Using Speech		**Using Screen**	
	Iteration 1	**Iteration 2**	**Iteration 1**	**Iteration 2**
English	20	27	3	4
Non-English (overall)	2	1	1	2
Totals	**22**	**28**	**4**	**6**

received from user type 'Unknown', with a rating of 5 for the robot answering correctly using Iteration 1.

The average duration of interaction could be seen to reduce from Iteration 1 to Iteration 2 for both staff and visitors, but not unknowns (Table (9.8)).

Post Interaction paper surveys were offered to a number of participants and 39 were returned. 12 participants returning the post-interaction survey used Iteration 1, 15 participants used Iteration 2. The remaining 12 participants were unmarked as Iteration 1 or 2. Of the 39 participants, 4 indicated the robot did not help them with where they needed to go. Reasons given were the following:
'Robot did not know where location was but was close'

Table 9.7: Average rating for first interaction by user type

	Robot Incorrect		**Robot Correct**	
	Iteration 1 (N=13)	**Iteration 2 (N=9)**	**Iteration 1 (N=12)**	**Iteration 2 (N=24)**
Staff (N=29)	3.67	3	4.63	4.73
Visitor (N=29)	3.57	3.4	4.5	4.92
Overall	3.62	3.22	4.58	4.83

Table 9.8: Average duration of interaction (sec)

	Iteration 1	**Iteration 2**	**Overall**
Staff	94.19	57.23	73.32
Visitor	66.38	54.38	60.22
Unknown	46.5	81.43	68.73

Table 9.9: Technology acceptance constructs

	Cronbach Alpha	**Mean**	**StD**
PU	0.75	4.39	0.74
PENJ	0.87	4.54	0.66
ITU	0.74	4.41	0.68
ATT	0.53	4.24	0.83
PEOU	0.02	3.89	0.87
ANX	0.88	1.64	1.06

'Directed to children ward. Outpatient is in ambulatory care.'
'Did not work, had to be rebooted'
'It gave directions to pathology instead. It needs better recognition.'

A short questionnaire adapted from the Almere model was used to assess the technology acceptance. Only constructs with all data provided were included. Constructs Perceived Usefulness (PU), Perceived Enjoyment (PENJ), Intention To Use (ITU), Attitude To Technology (ATT), Perceived Ease Of Use (PEOU) and Anxiety (ANX) results can be seen in Table (9.9)

Participants were asked *'When comparing the directions you received from the robot to those commonly received from other people in the past (not specifically staff working at the hospital reception), how clear were they?'* on a scale from 1 (*Definitely more clear*) to 5 (*Definitely less clear*). The majority rated the directions as *Definitely more clear*, see Figure (9.19) and reasons given were related to the visual aspect of the directions.

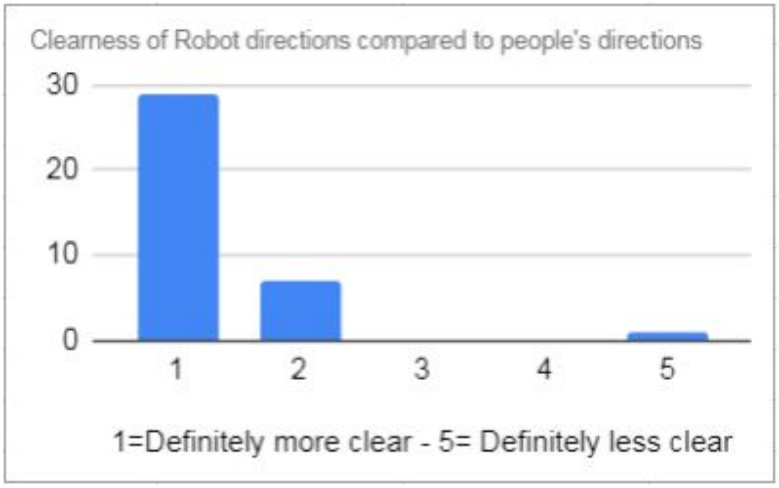


Figure 9.19: Clarity of robot's directions compared to people's

Reasons included were the following:
'It was accompanied by a video so I could see where to go'
'The video was very helpful in giving visual cues'

Participants were also asked *'When comparing the directions you received from the robot to those you have received from other technologies in the past (e.g. interactive kiosks in shopping centres or mobile apps), how clear were they?'* on a scale from 1 (*Definitely more clear*) to 5 (*Definitely less clear*). The majority rated the directions as *Definitely more clear*, see Figure (9.20) and reasons given were again related to the visual aspect of the directions. Reasons included were the following:
'Video was great'
'Again, the visual cues from the robot combined with clear verbal instructions'

Participants were also asked to indicate the affect on their mood, Figure (9.21), and the affect on their experience, Figure (9.22), at the hospital after interacting with the robot. Reasons given for the mood responses included:
'Pretty helpful quick and smart'
'It's fun'
'Because it's cute and smart'

Reasons given for the experience responses included:
'Made me smile'

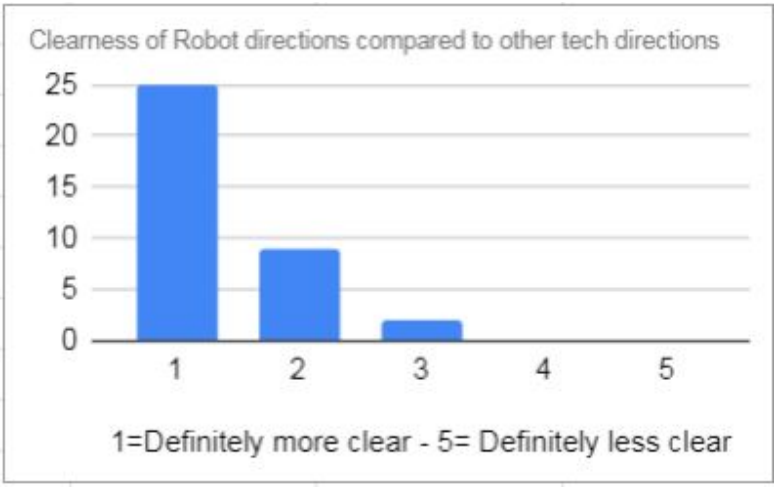


Figure 9.20: Clarity of robot's directions compared to other tech

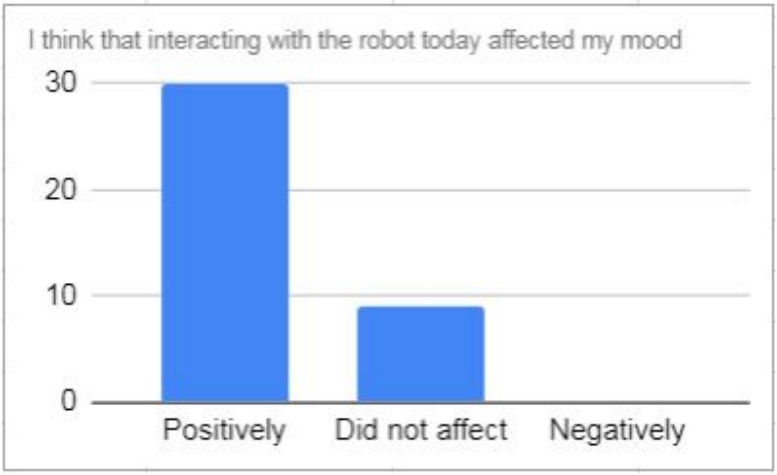


Figure 9.21: Affect of robot interaction on mood

'It's nice addition especially for kids'

Finally, participants were asked in a post-interaction survey *'How would you describe your experience with the robot?'*. Responses were predominantly of a positive nature, as can be seen in the word cloud of the top 15 words Figure (9.23).

Participants were finally asked in post-interaction survey *'Do you think there was something that the robot could have done to better assist you today?'*. Responses that indicated something further to be done are all reported here:
'In the video there was a point where it turned very fast and made me dizzy'

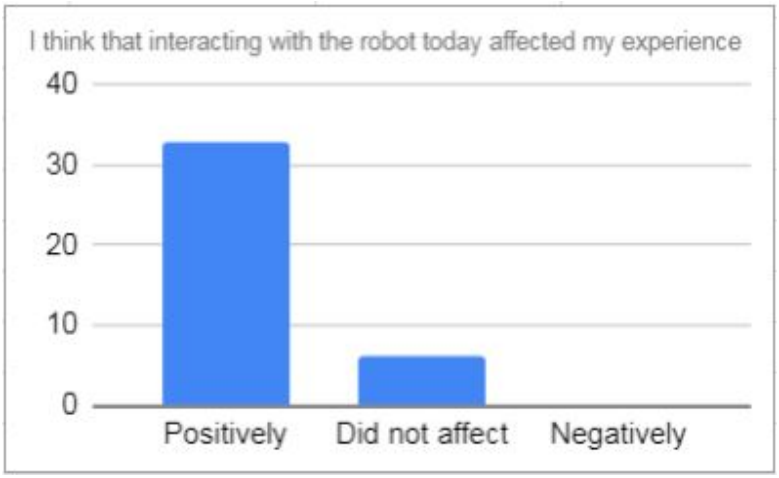


Figure 9.22: Affect of robot interaction on experience



Figure 9.23: How was your experience? The top 15 words.

'Require faster voice and object recognition'
'Will take time to enter obscure areas that are parts of other wards'
'Respond to single word location requests'
'Bigger and taller robot'
'Move around'
'Add more info, add Spanish, add dietetics department'

9.4.11.5 Study Discussion

As seen in the results, the majority of people using the robot at the hospital queried it regarding directions. This is a good indication that the task for which the robot was deployed was clearly understood by users. Additionally, the majority of users first used Speech to query the robot, indicating the intended modality of use was also comprehended. As such, H1 *The majority of hospital visitors using the robot will correctly use it to receive directions* hypothesis for the robot could be considered as validated. Secondly, as almost one fifth of the interactions were in a language other than English, H2 may also be considered as validated *A non-negligible proportion of visitors at the hospital will use the robot in a language different from English;*.

For H3 *Visitors using the robot will find the interaction easy, intuitive and enjoyable* visitors reported the interaction as enjoyable in the post-interaction survey and the interaction as positively affecting their experience and mood. Additionally, the modality of the interaction did not have to be told to participants—they intuitively spoke to the robot in their partaking of an interaction. In the Acceptance scale, Perceived Enjoyment (PENJ) was rated highly and Anxiety (ANX) as minimal. However, the Perceived Ease of Use (PEOU) and Attitude To Technology (ATT) items did not return a high enough Cronbach's Alpha to be considered as effective measures. Further analysis is required to determine why this was the case. As such H3 is only partially validated.

The Perceived Usefulness item from the technology acceptance scale indicated respondents found the technology highly useful. Additionally, the directions were rated as clearer then both people's directions (due to the visual nature of the response) and other technology's directions (verbal and visual). As such, H4 *Visitors seeking directions from the robot will find the directions given by the robot clear and useful* is considered validated.

For the final hypothesis, H5 *Staff will have a positive perception toward the introduction of the robot at the reception and understand its value*, only the "before" surveys

and a small amount of the "during" surveys were collected due to the imminent community restrictions with the COVID pandemic. As such, H5 is considered only partially validated.

Taking the above results altogether it is clear the research question: *R2—Study Is a multilingual social robot able to understand and handle wayfinding queries and successfully assist people to find their way at the hospital?* may be considered as positively answered. By answering this question we have confirmed the concept application discovered in our process to be a valid social robot application and shown it is also one that is both useful and enjoyable to use.

With regard to the first research question put forward in the Experiment Design step: *R1—Study How might we design an accessible, social robot wayfinding application that is able to assist users who may be non-english speakers, older adults or those experiencing varying vision and cognitive abilities.*

The use of the tri-fold lens in the application design phase assisted in the design of an application that was able to assist users who may have been non-English speakers. The design put forward was progressively improved and strengthened by re-iterative building and acting on the feedback from testing with multiple users. By providing a visual and verbal based directions application and augmenting the robot with the larger touchscreen we were able to successfully and innovatively address the varying accessibility issues.

It should be noted that there are limitations to our findings. Firstly, the findings will not apply to the entire population of hospital visitors. People who have fear or anxiety around new technology or robots may have chosen not to go near the robot in the hospital, as was observed in our previous public spaces design studies. Hence we would not receive their feedback regarding the use of the robot in the hospital. Similarly, people who fear 'robots taking jobs' may not have used the robot in an act of defiance to avoid supporting its future use. This concern of 'robots taking jobs' may be felt by staff members and not reported to the researchers. Secondly, additional experimentation is required to further validate the use of visual path wayfinding in locations other than this hospital. The hospital layout is an unusual one, flat and broad, with only two storey buildings, and this may have contributed to the success of the visual wayfinding. Thirdly, the hospital is in an area that is currently changing, with improvements to amenities and equipment that has been well-used over time. This may have contributed to the positivity with which the robot was accepted in the hospital, providing further change in the environment also matching with community needs (multi-cultural society).

9.4.12 Persevere, Pivot or Perish

Reviewing the application created for the hospital reception area and based on the results it would be safe to say that a useful application was created. People were able to successfully ask and receive directions, in five different languages. More than one person said they would like to see robots in all the hospitals giving multilingual directions. Had the COVID pandemic not occurred, this application would be one which could be persevered with for further experimentation and long term deployment. The reception is the first environment experienced by people arriving at the hospital. As such, it is imperative to reduce feelings of confusion, anxiety and disconnection. Introducing a multilingual social robot able to answer questions in multiple languages, including those of minority groups present in the local community, assisted those looking for help. The robot did not replace the human receptionists but augmented their role. The receptionist was able to deal with complex queries and leave the simpler task of providing directions to the robot. By providing multilingual support the application increased accessibility to hospital services. The robot was used by people as an alternative when there were queues forming at reception which may help reduce waiting times and when staffing shortages left reception unattended. The robot was able to assist with multilingual support, fulfilling the unmet needs of arrivals to the reception area.

Reviewing the project overall with a retrospective [99], the research team at the hospital revealed issues and further questions regarding the project. Items specific to the UX-HRI process are presented here:

1. What went well

    a) working on site

    b) user testing

    c) set up days

    d) the mix of team skills

    The co-design coding was also reported as effective by a developer on the research team: '*The process of co-developing on site was great. I believe it was essential for everyone to observe what was happening with users to then realise that previous choices had to be changed. This is particularly difficult to communicate to people that were not part of the observations on site.*'

2. What didn't go so well

   a) not enough set up days
   b) too many tasks for a small team
   c) arduous ethics process
   d) not enough time for system improvements

3. What questions do I still have

   a) how can we plan the time better?
   b) can we involve Ethics face to face from beginning?
   c) would there have been a difference in behaviour if it wasn't a research study?

Next steps and future iteration improvements of this application should include:

1. Increase the languages understood and spoken by the robot
2. Review existing and new languages for particular nuances to the healthcare domain and update the system accordingly
3. Re-take the video paths-to-location with a professional camera and proper lighting
4. Increase the directions able to be provided by the robot to include the entire Hospital directory
5. Provide translation services for the reception staff

Major new application features to investigate could also include:

1. Being able to connect to the hospital system and provide patient locations
2. View and confirm pensioner cards for parking discounts
3. View and scan forms and direct people accordingly
4. Direct contact aides or security for assistance with visitors
5. Call and manage taxis for patients and visitors

However, due to the COVID pandemic the continuation of this project is on hold for the current time and no further iterations will occur in the near future.

9.5 Discussion

The results show that the methodology was effective in discovering, designing and deploying a viable social robot application for a trial implementation in the hospital environment that addressed an unmet need. The resulting application was described as both useful and enjoyable to use. Importantly, the application was designed to be accessible to a broad proportion of the visiting population.

The measure for the success of Stage One of the methodology in the hospital environment was the approval of the document containing the results of the needfinding and proposed applications to be tested in the hospital. This document was approved by the Hospital Board and the Hospital Ethics Board, thus confirming success.

The Stage Two hypothesis, regarding co-design coding providing valuable improvements to the application, is validated by the reduction in interaction duration and the increase in accuracy in providing correct first-time directions. There was an increase in the rating given for Iteration 2, however it was only when the robot gave the correct answer. The co-design coding was extremely effective in quickly addressing issues with the user experience, interaction nuances and misses. This was due in part to the modular nature of the system, which meant issues could be fixed and released without impact to the application functionality. The use of the web-based dashboard for grammar editing was integral to the application's success. The ability to quickly add any missing items or synonyms of locations, edit sentences to be spoken by the robot and also view the accuracy of the robots responses made for extremely effective real time adaptation of the application to the environment.

Given the above results for the two stages, [R1] *Does the methodology work in the hospital environment?* can be confirmed. The methodology works in the hospital environment. Ethics approvals were met, the application ensured patient confidentiality and met privacy constraints, and the robustness of the service was ensured by both extensive testing and onsite adaptation with real time updates.

The design assumptions, worked with for the project, were added to during the ethics review and approval process. These were in addition to the emerging principles already being followed. Therefore, the design assumptions so far established still hold, confirming [R2] *Do the emerging design principles, so far determined as design assumptions, still hold?*, and have been enhanced for the hospital environment.

The final research question [R3]*Is the co-design coding effective in the hospital environment? Can we discern an improvement is possible in the application design from*

adding this to the process? is answered by the results from Stage Two and the feedback received on the application process by the development team. Co-design coding was effective at fast, real-time adaptation of the robot to the environment, leading to an improvement in the application design. Furthermore, it meant a second iteration could be coded and trialled, without losing valuable time by returning to the lab for development. It is concluded that this should be retained in the UX-HRI process.

Additional changes to the UX-HRI process also occurred. The size of the Hospital grounds and number of departments required a change to the methodology from that developed in Chapter 7. Differently, it was found we could neither answer the question '*What is the specific environment the robot will feasibly be interacting in?*' nor create a situated *How Might We* statement as described in the Chapter 7 methodology without first visiting the environment to identify the situated locations. Therefore the two steps were brought together. Additionally, by doing so, visits to the hospital were limited and avoided being an extra task or burden on staff, as each visit involved approvals, internal communications, visitor passes and the like. The initial meet and greet meeting in which the research team were paired off with staff members to walk around the hospital and learn about the environs while conducting informal interviews was a vital step as:

1. The research team had not conducted research in a hospital environment before so they required explanations of how various processes and areas worked

2. The staff had the opportunity to ask questions about the HCD research process, robots and AI (artificial intelligence) in an informal and relaxed manner, which assisted in allaying concerns and enabled relationship building

3. Visiting the different locations allowed the staff to advise on which areas they found problematic, for example no WiFi or mobile phone reception; areas where visitors and patients could commonly be found seeking assistance; and typical experiences, occurrences or interactions they had experienced in each location

4. The timing of typical visitor and patient flows were advised, for example patients for the hand clinic or renal dialysis would be arriving early morning, around 7am, with 2pm another popular time.

5. Importantly, staff were able to advise on situations that could occur with visitors or patients who may be in sensitive or highly emotional states, where and when these were likely to occur.

In the step of Persevere, Pivot or Perish, the use of a traditional retrospective to gather reflections from the team may have been enhanced via a more modern technique. Traditional retrospectives are useful when there is limited time to generate insights [99]. Modern techniques which include fun activities may have been of greater benefit [258], had the project not been halted due to COVID.

9.6 Reflections and Learnings

There are broader implications of this design study in the Hospital environment for the UX-HRI methodology. Important in this respect were the challenges faced in this task.

Challenges in conducting human-centred design research in hospitals have been well documented [154, 310]. The outline of the challenges are presented here with our specific experience in each of these areas. Of the challenge areas, unique challenges to social robot research are identified. This may assist in providing social robot researchers with the ability to anticipate potential hurdles when conducting research in the healthcare environment.

Groeneveld *et al.* describe three broad themes of challenges for HCD research [154]. I use Groeneveld *et al.* themes to guide the reflections of the experience at the hospital, as follows:

1. *Challenges in practice: Conducting fieldwork, Involving end users, Dealing with sensitive situations*

    a) Number of interviewees willing to take part in the interviewing process—In our previous DT exercises, participants would absorb the participant information sheet quickly and provide instant verbal consent of their willingness to be interviewed, adding to the more natural, conversational feel in interviewing, and high numbers of participants would agree to a quick conversation. In the hospital environment, presenting participant information sheets and consent forms resulted in some people turning away from being interviewed. This may have been due to a reluctance to deal with or read through paperwork, due to lack of time or heavy mental load. Additionally, a number of people felt we were looking for negative feedback and made it quite clear that they would not share anything that was in any way detrimental about the staff or

hospital. We subsequently adapted our introduction to make sure that this was made clear that it was not the case.

b) Emotional situations—Sensitive situations did indeed occur, with emotional responses happening on a few occasions. Each time, no notes were taken. In some cases, people would vent about their situation then thank the researcher just for being there and listening. This added to the observation that social connection was important in the hospital environment. It also highlighted the need to consider the impact the research may have on the researcher.

2. *Challenges in project management: Managing relations, Building understanding, Communicating the value of design*

a) Managing expectations–when communicating the capabilities of AI and social robots we had to be careful that this was without implying that it was what could or would be implemented. We used video demonstrations of the Pepper robot in action to assist in the understanding of capabilities.

b) Location challenges—Staff were invited to take part in the brainstorming process however none attended. Our learning from this was that the session should have taken place at the hospital, as events outside the workplace limits numbers of attendees.

c) Communication regarding AI use and privacy impacts—Building understanding of AI technologies, broadly speaking, such as the social robot using speech recognition and natural language processing, differences between facial detection and facial recognition, mapping and wayfinding, were vital for management staff support and understanding. Addressing how these technologies impact privacy and how the application would protect privacy were also crucial to gaining support.

3. *Generic challenges: Attuning to time and financial restrictions, Establishing rapport*

a) Ethics submission—the Ethical governance board submission process for healthcare was similar to university ethics committees yet also more challenging due to the longer time of review, the questions regarding the AI in use by the robot and the number of people involved in working together across institutions to make the submission. Each review would end with further questions and changes to be made.

In summary, the challenges encountered were not insurmountable. The difficulties of undertaking HCD in healthcare practice is not unknown. It was possible to anticipate when potential hurdles may arise and deal with them proactively. While it cannot be assumed that these specific, listed challenges would occur outside this specific project, they are of a broad enough nature that commonalities can be seen to emerge from the experience of the three design studies:

1. Organisations' employees have many questions regarding Artificial Intelligence (AI) and how it works in the various ways with the robot.

2. Ethics require detailed explanations regarding AI and the privacy implications of use

3. Onsite testing with users is invaluable to the success of the robot application. The ability to iteratively and spontaneously make improvements in the real world environment from the on-the-spot evaluations provided by the intended audience allows incredibly fast and responsive changes to be made. This reduces the need for extensive effort and unnecessary documentation, as per Lean UX principles.

4. Onsite testing with users is invaluable to the success of the robot application, however, even this can be misleading. What works in testing may not work when put to use in the direct social circumstances of the situation in the real world. For example: onsite testing by users of direction giving; as users were 'testing' they would stay, and complete the feedback rating screens on the robot. In real life situations, users would get their directions and go, the majority did not stay long enough to give a rating. Hence the ability to adapt the robot to the specific circumstances of the situations encountered in the environment is paramount.

Reflections on the design of the robot behaviours also discovers a commonality among people regarding spatial distancing from the robot. Observation of interactions across all studies identified an unseen spatial boundary around the robot, beyond which people did not expect any robot interaction to occur. People expected the robot to pay attention to them when they stood in the front area of the robot, but not from behind the robot or too far off to the side. This appears to be a social interaction norm that is extended to the humanoid robot as a social entity, and is known as proxemics. Proxemics is a theory of non-verbal communication, that describes how people perceive and use space to reach communication goals [157]. Specifically, spatial distancing between humans

is an integral component of communication in social interaction. Spatial distancing is likewise of importance in human robot interaction, with significant investigation [90, 278, 374, 425] and inclusion in introductory HRI texts [23].

In privacy-sensitive robotics, the importance of proxemics in privacy and the complexity of addressing personal space expectations that change in different situations is noted [327]. One way of addressing proxemics is with technology, whereby contextual factors are integrated into a system that dynamically determines the optimal spatial distance for the situated interaction with respect to the humans around it. While this is ideal, in the case of social robots interacting in a public space, with today's technology and socio-cultural expectations, the aspect of dynamically changing the distance at which the robot perceives people lends itself to uncertainty. Being able to change the distance obscures the degree of surveillance by the robot. Hence, to prevent fear of surveillance and provide privacy protecting behaviour, it is proposed for further studies, that a *'zone of information processing'* be specified for the robot, taking advantage of this propensity of people to already expect a boundary to the robots perception. A human analogy of this concept may be a person with short-sightedness, only able to recognise you when stopped, within a close distance, and not recognise you at all when in motion.

This information processing zone would then determine the extent of the information flows that are processed by the robot. The zone may be determined within the design stage of the concept application, as part of the mapping process for the robot within the specific location. The mapping allows an expectation of robot use and movement and demonstrates the privacy practice of minimising data collection.

Furthermore, by only processing information from within the specified zone, privacy invasive events may be prevented before they occur. It may be as straightforward as a heuristic zone of 2 metres in front of the robot, when it is stationary. By actively determining and developing for the intended spatial extent of information processing of information flows, it is suggested that it may actively fulfil and build on the social norm expectation. This will therefore maintain the appropriate information flow for the specific context, as per Contextual Integrity theory (CI) [286], which defines privacy as appropriate information flow according to norms specific to social contexts.

This zone of information processing could function with respect to the expected information flows, to be considered in a specific environment; see Figure 9.24 for suggested examples. The information flows from a person towards the robot should be processed dependant on the situated, social context and the principles of Privacy-by-Design. The information flows are able to be distinguished between user initiated, for example a per-

son speaks to the robot, or non-user initiated, for example recognising a user is sitting in a wheelchair. Non-user initiated information flows should only be used in the interaction if it is contextually justified. For example, the wheelchair user may expect directions provided by a robot to not include using the stairs, as it is publicly observable they are in a wheelchair and will require a ramp or lift to travel. A distinction should be noted here between the information flows that are publicly observable and information flows which make judgements on people's attributes. In social situations, providing information to someone when it is clearly at odds to their publicly observable appearance may be considered rude or inappropriate. For example, offering a child discounts for buying wine. Contrastingly, providing information to someone based on a judgement, subjective or otherwise, of their publicly observable appearance may also be considered rude or inappropriate. Hence a suggested difference is noted between information flows as per the following:

1. Age and Age Range — it is publicly observable that a person is either child or adult. Hence the information of importance for decision making in interactions may be thought to be only the end range of possible ages, as opposed to a distinct age estimation. For example, a child is less than 18 years, and this may be required to be estimated for legal reasons. However it may be a breach of social norm if used for adults, especially in regards to stereotyping and age-related discrimination. Judging someone's actual age may be considered unnecessary information collection and may also lead to age discrimination if used in decision making in an interaction. Age discrimination is unlawful in Australia and is linked to ageism [14]. Ageism is '*a social construct of old age that portrays ageing and older people in a stereotypical, often negative, way.*' [17, pg. v]. Stereotyping is also highlighted as a concern in development of social robots for older people [227, 228, 406]. It is suggested for the design assumptions, that an adult's estimated age may be considered private information, (Privacy of the Person) and should only be used or transparently collected with explicit permission.

2. Height and Height Range — Height is again an area that only requires a range measurement, as per Age. Collecting someone's height information should only be with explicit permission. Storing a person's height may be considered to be collecting more information than is needed unless a genuine purpose is specified.

3. Gender and Gender Presenting — Gender information should not be considered permissible to use or collect without explicit permission. In certain cultures, there

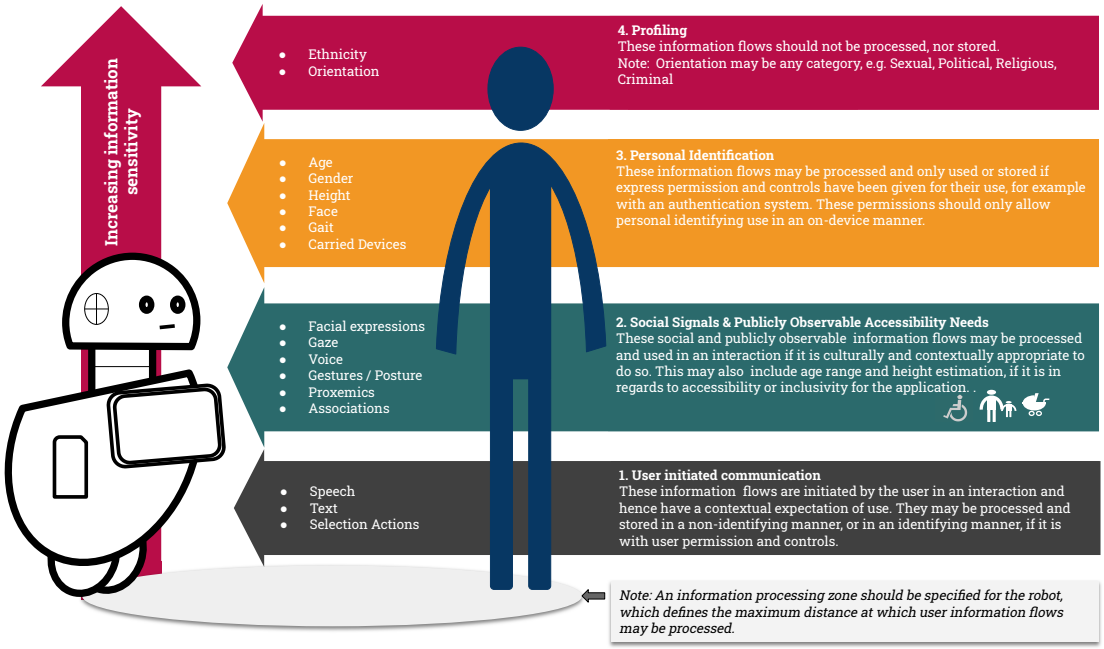


Figure 9.24: Information flows for social robots in public spaces

may be a context for gender presenting processing to occur, based on publicly visible attire. However, for institutions wishing to support gender equality, it may be considered that gender information should be avoided to prevent possible discrimination or re-enforcing of gender stereotypes.

A summary of the learnings from this study is provided as per the following:

1. Building employee's understanding of AI assists in garnering their support and furthermore assists in this knowledge being transmitted to other, unseen employees. Next time, a workshop could be dedicated to providing this information to staff.

2. Dedicated attention to AI in ethics proposals containing robots, even when the proposal does not contain proposed use of personal information, may assist in reducing ethics queries related to AI.

3. Onsite testing with users still does not completely cover all real life situations and circumstances that may occur.

4. Retrospectives are a vital step in the persevere, pivot or perish step to ensure mistakes are not repeated.

5. Web-based customisation tools for robot interaction are invaluable for quick updates and could be used by frontline staff should the robot be deployed in the environment.

6. The zone around the robot in which people expect a response from the robot to occur may also be helpful for defining the boundary at which contextually appropriate information processing by the robot should occur. This may assist in avoiding fear of surveillance however is still to be investigated.

9.7 Next Contribution

This final design study finishes the Building, Intervention and Evaluation phase within the Action Design Research (ADR) process. In the next chapter, the final ADR phase involves bringing together the learnings from each design study and providing the resulting final framework.

Part IV

Formalisation of Learning

CHAPTER 10

UX-HRI Framework for Social Robot Application Design

"Quality of design is distinguished not merely by technical skill of execution or by aesthetic vision but by the moral and intellectual purpose toward which technical and artistic skill is directed." Richard Buchanan [52, p. 37]

This chapter completes the final stage of this Action Design Research (ADR) inspired process, bringing together the previous three ADR stages for *Stage Four: Formalising Learning*. In this chapter I formalise the knowledge gained from observing, evaluating and analysing the act of producing a new, theory-ingrained artifact into existence—the social robot application, over three different design studies and environments.

10.0.1 Part III Summary

In Chapter 7, the Building, Intervention and Evaluation inspired Design Study investigated the use of the Lean UX process, incorporating Lean Start-up, Design Thinking and Agile practice, to enable identification of potential social robot applications in a busy international airport. The process produced potential applications that addressed

unmet needs at the airport and were tested onsite. Data collected from this study was unable to be shared due to commercial sensitivities. However the project was reported as successful by the organisations involved and provided a first opportunity for the Lean UX design process combined with HRI theory to be instantiated, referred to as UX-HRI. Learnings included the importance of media releases, such as online articles, magazines and video, to set people's expectations regarding the robot.

In Chapter 8, the UX-HRI design process with a focus on Privacy-by-Design was followed, creating social robot applications that utilised privacy sensitive information at a government-run space for entrepreneurs. The effectiveness of maintaining contextual integrity and following Privacy-by-Design to provide clear, transparent data collection practices and choices was discovered.

Finally in Chapter 9, the complete UX-HRI design process, incorporating the structuring of the design space perspective and Privacy-by-Design were used to create an innovative social robot way-finding application for use in a hospital environment.

The principles of ADR were followed throughout the research, with mutually influential roles, reciprocal shaping, and authentic and concurrent evaluation throughout the design studies. The goals of socially responsible design were realised: via following privacy principles, both governmental principles and Privacy-by-Design; and beyond, by combining the approaches of Contextual Integrity theory [287] and the Seven Types of Privacy [120] to realise social responsibility at an application level. In doing so, the final framework was reached, described in the following section.

10.1 The UX-HRI Framework

Provided here are the generalised outcomes, presented as a framework named UX-HRI, that includes the following:

1. A UX and privacy focused design and development process for social robot applications in public spaces

2. A design space structure for discovering potential social robot applications in public spaces

3. Information flows and privacy considerations for social robot interactions

4. The design principles for socially responsible social robot applications in public spaces

The outcomes are intended to be used together however they also have stand-alone benefit and can be used separately. For example, the design principles may be used as a checklist to assess a current implementation of a social robot application in a public space. The information flows may be used to quickly categorise possible privacy impacts. Using the UX-HRI framework as outlined enables discovering, designing, developing and implementing socially responsible social robot applications for commercial social robot platforms in public spaces. The framework does not claim to be exhaustive nor the only way to design social robot applications. This framework is built on the conclusions from Part II and the learning from the Design studies of Part III: Chapters 7, 8 and 9.

The components of the UX-HRI framework are outlined in the following. A reminder is given here that this framework is specifically for social robot applications of commercially available social robot platforms in public spaces. It is not meant as an exhaustive inclusion of everything regarding social robot application design however it does provide a direction for innovative, future social robot implementations.

In the following section is presented the main component of the UX-HRI framework, the design process. It was used to successfully conceptualise and build social robot applications (artifacts) for three different environments, all publicly accessible places requiring shared use by the public of a social robot. The practice of building the applications enabled constant evaluation and adjustment of the design process, while also allowing learning around design decisions and practices.

10.2 UX-HRI Design Process

Provided here is the UX focused design process, evolved from Design Study 1, Chapter 7, with the additional learnings from Design Studies 2 and 3. It is presented here with the assumption that there is a mutli-disciplinary team assigned to work on the project, from a research lab, organisation or combination of both, and that the intention is to use a commercial social robot platform. It allows discovery within the first few steps if commercially available social robots are not suitable for the intended environment and that other options should instead be investigated, see Figure 10.1.

Note in some circumstances, the steps and individual tasks may need to be reordered and repeated as required. However, the following list is the recommended order:

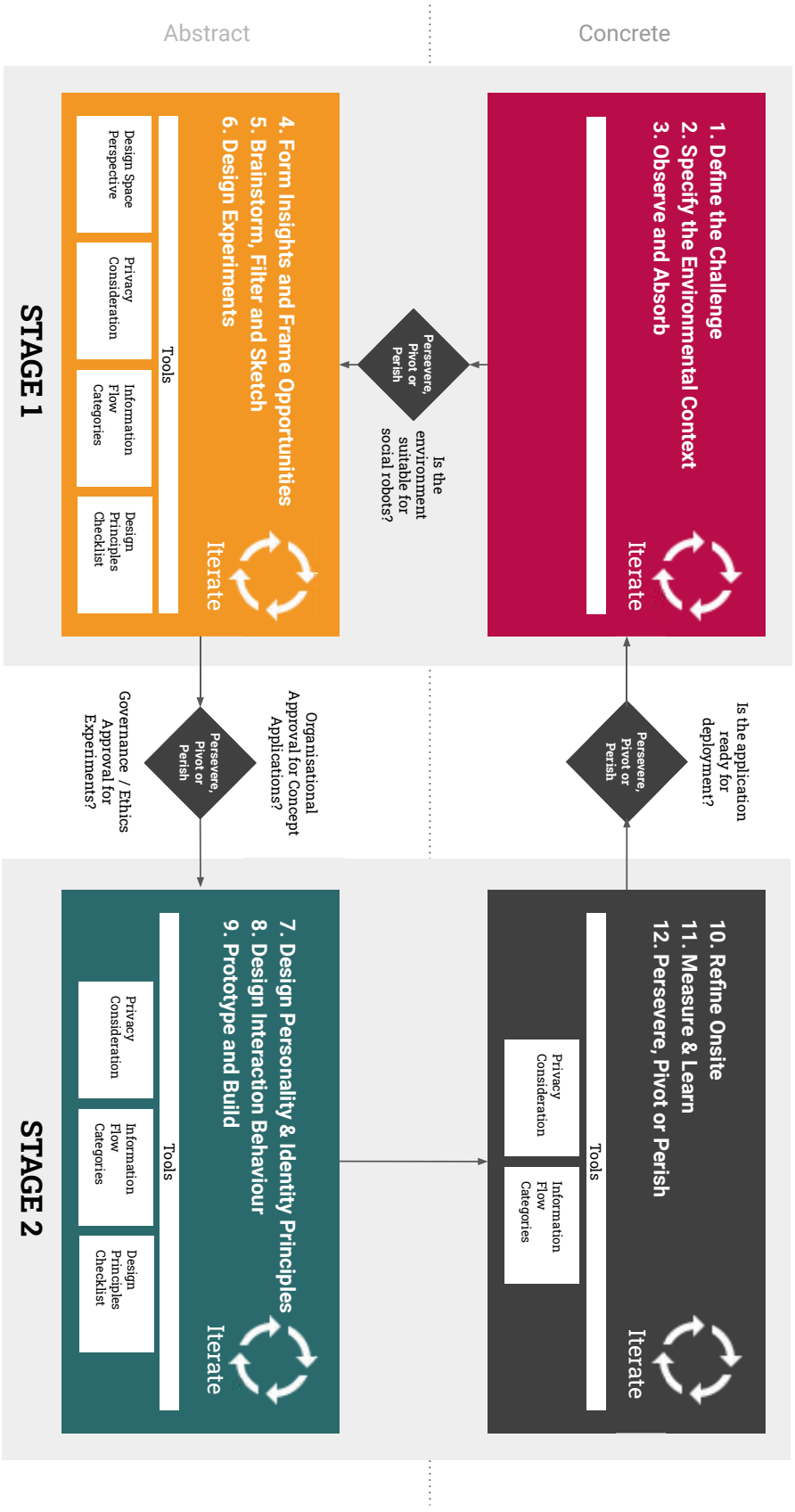


Figure 10.1: The UX-HRI Framework

10.2.1 Stage One

1. **Define the Challenge**
   First identify the project challenge and what is going to be investigated with an overarching, how might we statement *e.g.* "How might we use a social robot to improve the experience at the *public space*". Secondly, identify the team members who will be involved, encouraging cross-discipline members.
   Outcome: 1. How-Might-We (HMW) statement 2. Team members.

2. **Specify the Environmental Context**
   This step requires identifying the specific situated context and answering the question *"What is the specific environment the robot will feasibly be interacting in?"*. This involves visiting the location to identify the specific locations that may be feasible for a social robot in the selected public space. For example, the robot may need location attributes such as easy access to power, manageable acoustics, ramps that must be no greater than a 15 degree angle, safe space to navigate and to be free of potential hazards in order to function in the environment. Such visits should involve the following steps:

   a) Visit the location.
      If possible, speak with staff to discover if any area is unsuitable due to regulations or usage. This may quickly narrow down available areas for a robot.

   b) Record any physical boundaries, attributes and location sensitivities.
      For example, the width of a corridor may be too narrow to allow a robot and nurses moving a hospital bed to traverse easily, special attention would have to be paid to how people would get past or be able to step aside. Additionally, heavy doors or lift buttons that are in odd locations may make it difficult for the robot to navigate those areas without assistance. Areas such as opposite the entrance to a possibly sensitive location, for example the toilets or private clinic, should also be noted, as placing a robot in these areas may be considered an impingement on privacy.

   c) Highlight on a floor plan the available areas, marking the attributes, boundaries and sensitivities.
      Using coloured indicators allows understanding at a glance which areas can be navigated, require assistance/adaptation or should not be entered. Use

the map to also understand where more than one robot may be required, for example a shopping centre may have two main entrances, with no feasibility of a robot traversing between them.

d) Identify the most feasible locations from the map.
For example, this may be the reception area, the car park entrance and the food court main entrance, as all 3 locations have robot friendly accessibility attributes, no location sensitivities and easily navigated.

Armed with the knowledge that these locations are the main areas to investigate, re-define the challenge with the location-specific information. For example:
"How might we use a social robot to improve the experience in the reception area, car park entrance and food court main entrance of the *public space*."

Note: The floor plan is used in this first assessment to determine where the robot may physically function. If the owner of the space is willing, the floor plan may be used as a guideline for changing or adjusting the environment to better suit a robot.

Outcome: 1. Situated How-Might-We statement; 2. Floor plan of location marked with physical boundaries, attributes and location sensitivities.

3. **Observe and Absorb**
This task involves bringing the entire team together and visiting the specific identified locations to understand the environment, to observe and empathise with people present in that environment, absorbing the feeling of being a participant in the environment and the social expectations this entails. Needfinding [299] interviews are conducted with all people present and willing in the specific location, including any staff. It is important to visit at different times of day when people may be present with different purposes. For example, in the hospital environment, early morning visitors had little time free, were sometimes anxious and wished to go straight to their appointments. Afternoon visitors were more relaxed and were there to visit friends or family who were patients, and had more time free to interact. This has a direct impact on the design of the robot behaviours, especially in regards to interactions collecting feedback. Interview questions to be asked can include:
"How did you feel when you arrived here and why?"
"How does the current experience here make you feel and why?"

"What's the worst part of being here and why?"
"What's the best part, or a previous good experience, you've had here and why?"
"If you could change anything about the experience here, what would it be and why?".
Every person present in the location can provide valuable experiences to learn from and understand from their viewpoint. Staff members in the locations are especially relevant as they have the most knowledge from their day-to-day interactions with people in the space, accumulated over time. Different interview questions may be asked of staff, such as:
"How do you think people feel when they arrive here and why?"
"What's a previous good/poor experience you've had helping a person here and why?".
"What do you think most needs addressing here and why?"
Outcome: 1. Team members with an awareness and direct experience of the environment, allowing understanding of the social context of the environment and importantly, allowing an understanding of the subsequent privacy expectations in the environment; 2. Observations and feedback notes.

4. **Form Insights and Frame Opportunities**
   Insights are formed by firstly creating an empathy map for each location based on the interviews and observations conducted. Key emotions are determined based on the feelings reported by participants in the interviews and also the team's experience within the location. The empathy maps outline quadrants Think, Say, Feel and Do. Insights into opportunities and pain-points, especially from surprising tensions, are noted.

   Journey Maps are then created based on the majority of behaviour observed and reported for each location. The journey map may be specifically for a type of user, for example a customer or employee. The activity, the corresponding emotion and the insight, from each step of their journey are mapped and used to promote discussion. This discussion culminates in the framing of opportunities via creation of How Might We statements. The HMW statements enable addressing of the unmet needs of the people within the location via focused brainstorming in the next step.

   Outcome: 1. Empathy Map with Insights into pain points and opportunities; 2. End-to-end Journey map for each location; 3. How-Might-We statements for each location.

5. **Brainstorm, Filter and Sketch**
   The How-Might-We (HMW) statements generated from the pain-points and insights

into the user journey are used here as platforms for idea generation. It is suggested the team decides the best method, whether think aloud or silently writing and later voicing, based on the team's previous experience with brainstorming. Building on others ideas and voicing support for ideas is encouraged. No judgements of ideas should be made, ideas are solution agnostic with no limitations. Ideas can be progressed and encouraged with themes on privacy, ethics, budget, worst idea possible [1], most fun ideas, most empathetic idea. Once a number of ideas are generated for a location, ideas are furthered by additionally asking "How might we *use a social robot to...*" with the given HMW statements.

Ideas are then grouped into concept themes. Discussing the themed concepts using the tri-fold design perspective lens of social agent, interactive media and communication medium, Figure 10.2, allows substantiating of concepts and inspires further idea generation.

The concept ideas should be filtered via Feasibility, Viability, Ethical and Community value, then the most desirable voted on by the team. To undertake this process, key considerations for any potential application are discussed. These may include staff collaboration requirements and the impact of involvement on current system processes, technical feasibility and connectivity to existing systems, and importantly, ethical considerations such as privacy. Answering the question *"Will any personal information be collected, stored, used or disclosed in the use of the application?"*, which is the first step of a Privacy Impact Assessment [12], allows understanding of the privacy considerations. This discussion should also include impacts regarding the Seven Types of Privacy [120], which can be seen in Figure 10.3.

Concepts which will clearly violate privacy should be removed from voting. These may typically include any concepts that involve surveillance and profiling. Concept applications that use privacy impacting technologies, such as facial recognition, need to be identified for further discussion and privacy impact analysis.

Once the concept applications have been rigorously discussed and assessed, storyboards of the most desirable, according to individual team members are created. This allows visual understanding of how the concept applications would be used, from start to finish.

[1] Worst idea possible is used to encourage creativity.

The concept storyboards are narrowed down further via mapping the ideas on a high/low quadrant of Ease of Implementation vs Impact. Further voting may then be required by the research team to decide the most desirable, brand new experiences for the environment. Once decided, full end to end storyboards are created for the proposed applications.

Outcome: 1. Privacy-sensitive concept applications with full end-to-end storyboard.

6. **Design Experiments**
   This is the final step of Stage One, where hypothesises are articulated for testing the viability of the final concept applications from the Brainstorm step. The measures and criteria for success of the hypothesises are established. There may be no initial criteria for success for some hypotheses as the measure itself may be a trial.

   The planning for the prototype also begins with a list outlining the Minimum Viable Role for the robot and the concept applications, to validate the hypothesis. **Outcome:** 1. Hypotheses, Sub-Hypotheses, Measures and Test Success Criteria; 2. Minimum Viable Product/Role outline.

   The culmination of Stage One ends with the approval of the proposed concept applications and testing of the design by the organisation. In research organisations this may be followed by approval from the Ethics board for the subsequent conducting of an experiment with the prototype application. It should be noted that the above steps may be repeated a number of times, with multiple workshops, as information is understood and revealed by the process.

10.2.2 Stage Two

Stage Two begins with the approval received from the organisation and relevant Ethics boards. Once approval is given, the building of the prototype application can begin. This stage comprises intensive design and development in an iterative design process. It involves paper prototyping, role play, and soliciting user feedback throughout the process. The design and development phase can be separated into three components which should be run concurrently, depending on the team mixture. These involve defining the robot personality and identity principles, designing the interaction behaviour, and undertaking the technical development required to support the realisation of the first two. Throughout this stage, the design principles for socially responsible social robot application design can be used. These can be seen in Figure 10.5.

1. **Design Personality and Identity Principles**
   The process of designing the robot personality and identity principles begin with establishing a foundation personality for the robot. The personality should be representative and consistent with the values of the organisation, the public place in which the robot will be placed and the role the robot is going to perform. Given the expectation of the robot providing a shared use service in public spaces, a starting baseline for the personality for the robot is as simple as that from early software design *"design it to behave like a likeable person"* [76, p. 160] i.e *"...respectful, generous and helpful"* [76, p. 161]. This starting point of politeness assists in preventing cases of developing robot personalities that may cause consternation in users regarding stereotyping, condescension or over-familiarity [139] While there are roles that require a bubbly or sassy personality, these should always be on top of an underlying respectfulness and helpfulness towards humans by the robot.

   Using the prototype Minimum Viable Role outline and the end-to-end storyboard the personality principles for the robot can be defined using the categories Who, What and How. Personality features that would be suitable for the role description are defined for the "Who" stage, with descriptors. For example: Friendly, Helpful, Jovial, Fallible. Under the heading "What", what the robot should do should be listed out with the expectations for the robot in the specific role, in the nature of a job description. Thirdly, a description of how the robot should interact, based on its personality and role description, is outlined for the "How" category.

   Additionally this step requires the branding and visual design components of the concept application to be completed. These should be consistent with the robot's role in the organisation it is representing. Once these are completed, marketing materials can be created to set user expectations regarding the use of the robot in the location.
   Outcome: 1. Personality Principles that describe Who, What, How; 2. Identity Design which includes branding and visual styling of the robot. 3. Marketing materials such as images, video, articles and social media to set user expectations.

2. **Design Interaction Behaviour**
   The Interaction design stage involves creating the behaviour flows for the end-to-end journey of the user in the environment and the interaction with the robot at the various touch points. This includes the necessary movements, speech and multimedia that the robot will be employing. As with the Personality design stage,

it involves continuous user feedback, and utilises sketching, paper prototyping, mapping and role play.

In addition it provides the position and mapping schematic of where the robot may travel or position itself in the specific location. This is a vital consideration as it also allows mapping of the information processing zone of the robot, which must be specified to prevent the possibility of surveillance, or fear of surveillance, occurring. The possibility for unintentional, privacy impacting processing of information by the robot, may occur during this stage of the design phase. Consideration of the possible information flows to a social robot may assist in identifying which processing of information may be an issue (see Figure 9.24 for a non-exhaustive list). A mapping of the information flows, to be processed by the robot for the application, should be created, based on the contextual expectation of the interaction. This can then be used in a Privacy Impact Assessment should the application be collecting sensitive information.
Outcome:: 1. Position and Mapping Schematic that includes travel zones and information processing zone; 2. Information Flows to be collected within the information processing zone 3. Behaviour Flow for each specific location/activity that details the speech, motions and screen expectations for the behaviour.

3. **Prototype and Build**
   This step is run concurrently with the design steps. It relies on continuous, iterative, user testing and feedback. The development of the prototype application is in accord with the Privacy-by-Design principles. This extends also to the development or customisation of any customisation tools for implementation, which may also have privacy impacts.
   Outcome:: 1. Minimum viable product prototypes, ready for testing with users onsite 2. Web accessible customisation tools for quick, adaptive changes onsite

4. **Refine Onsite**
   In this step the robot is deployed with its new capabilities to the environment. This step includes onsite adaptation of the robot to the specific environment in a method described as co-design coding. This method brings together the people in the environment to not only test the application but also guide any changes for future iterations. Once the application has been customised to the specific location, experimentation may begin. The application may be further refined with staged

releases for onsite iterative testing. **Outcome:**: 1. Customised application to the environment.

5. **Measure and Learn**
   This step involves the hypotheses defined in the 'Design Experiments' stage being tested, using the measures and success criteria determined previously. During this step it is also possible to run staged iterations of the application onsite, if run concurrently with the Refine Onsite step.
   Outcome:: 1. Learnings from the experiments. 2. Validated/Invalidated hypotheses.

6. **Persevere, Pivot or Perish**
   In this stage the insights and implications from the environment, concept applications or experiments are reviewed and the next steps decided. This may be iterating again from any stage or step within the design process to persevere or pivot the application, or may even involve deploying the application for use in the environment. An important component of this step in the final stage is the facilitating of a retrospective on the application implementation onsite, to assist in learnings for further iterations.
   Outcome:: 1. Next Steps: which behaviours and concept applications to progress, what to pivot towards or what to drop, and which stages of the methodology to return to. 2. Retrospective learnings from implementation.

By using the above framework and accompanying design tools as provided in the following, organisations have a framework for: understanding how to discover potential social robot applications for their organisation; determining if a commercially available social robot is a suitable fit for the location; and finally how to design, develop and implement the social robot application so it is a good user experience that meets the needs of the people within the intended environment, in a privacy sensitive and socially responsible manner.

10.3 Social Robot Design Space

An integral part of the UX-HRI framework is the Social Robot Design Space, as described in Chapter 6 and built on in the subsequent Design Studies. It involves structuring social robots as sitting at the intersection of the physical, digital and social realms, within the

situated context of the physical interaction. Three perspectives are framed as a lens to allow the full possibilities of social robots to be explored when designing social robot applications.

10.3.1 Social Robot Perspective for Application Design

1. Social Robot as Social Agent
2. Social Robot as Interactive Media
3. Social Robot as Communication Medium

The Social Robot Application Design space, comprising the social, physical and digital realms, is illustrated in Figure 10.2. The social robot as communication medium can be understood to be bridging the divide between the physical and digital realms.

10.3.2 Privacy Considerations for Socially Responsible Design

To ensure socially responsible design, it is vital to consider privacy implications throughout the design process. Above and beyond using the principles of Privacy-by-Design [62], Privacy Legislation [292] and corresponding Privacy Impact Assessments [12] as recommended and stipulated in the Design Studies, two privacy perspectives are provided for the Design Space, to aid the design process. These are based on the theory of Contextual Integrity (CI) [287] and the Seven Types of Privacy [120], as first outlined in Chapter 6 and explored in Chapters 8 and 9. Firstly, the Seven Types of Privacy are mapped onto the social robot interaction design space, provided in Figure 10.3, to review the areas of possible privacy impacts in a situated context.

Secondly, considerations for mapping possible information flows for social robot interaction in a situated public space, for CI theory, are provided in Figure 10.4. The areas critical to consider, regarding possible information flows for social robots in public settings, are divided into the categorisations outlined in the following.

1. User Initiated Communication
   These information flows are initiated by the user in an interaction and hence have a contextual expectation of use. They may be processed and stored in a non-identifying manner, or identifying manner if with user permission and controls. The collection of this data may be considered *'visible'* to the user.

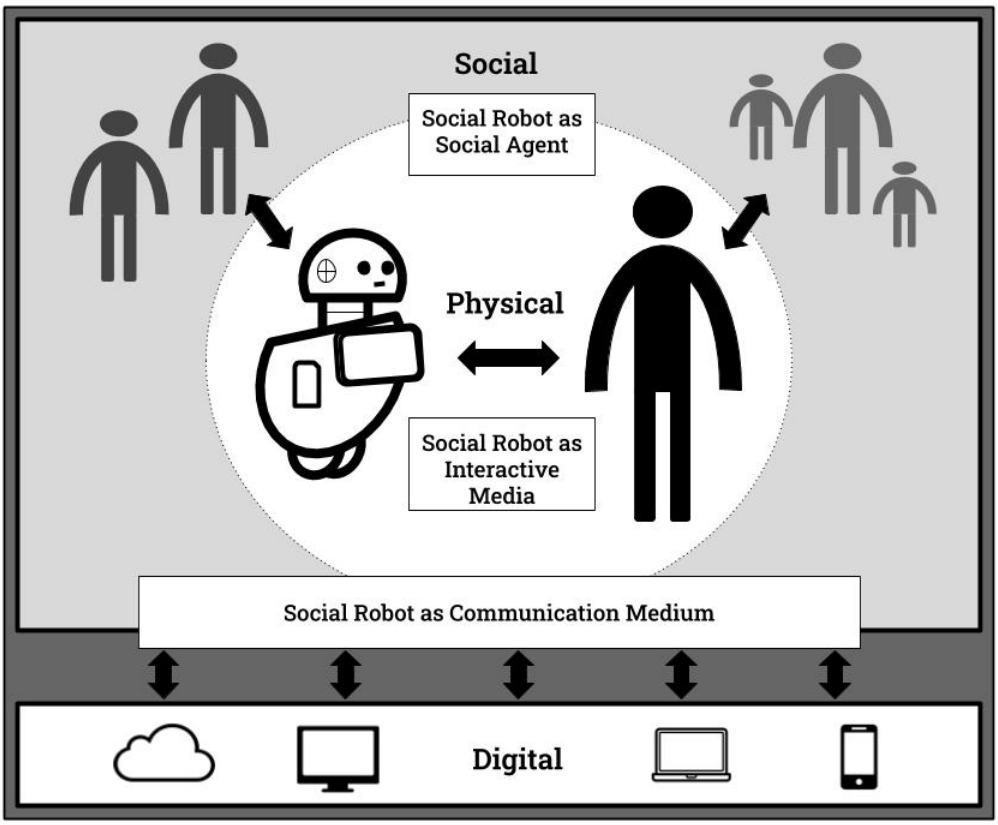


Figure 10.2: The design space perspective for social robot application design

2. Social Signals and Publicly Observable Accessibility Needs
   These social and publicly observable information flows may be processed and used in an interaction if it is culturally and contextually appropriate to do so. Any storage of this data should be temporary, and non-identifying. This may also include age range and height estimation, if regarding accessibility or inclusivity for the application. The collection of this data may be considered *'invisible'* to the user, yet a contextual expectation may exist regarding the appropriate use of the data in a social interaction.

3. Personal Identification
   These information flows may be processed and only used or stored if express permission and controls have been given for their use, for example with an authentication system. These permissions should only allow personal identifying use

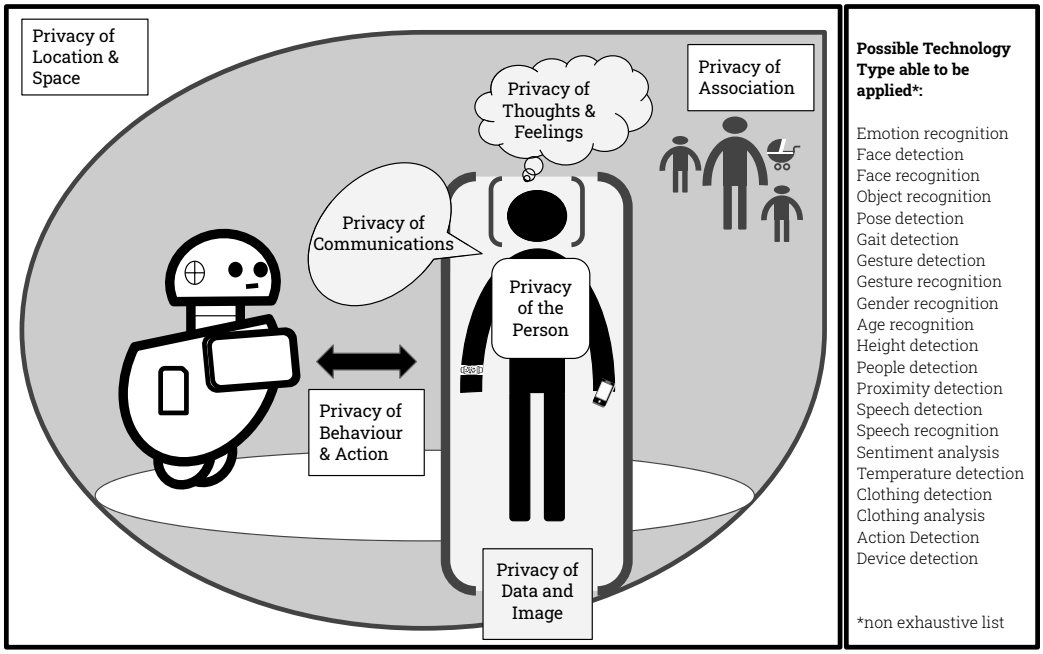


Figure 10.3: Considerations for social robot application design using the Seven Types of Privacy from Finn *et al.* [120]

in an on-device (on-robot) manner. The collection of this data may be considered *'invisible'* to the user, yet may become more visible with an authentication system, and corresponding notifications and controls. The contextual expectation is that this data is not processed nor used without consent by the user.

4. Profiling
   To ensure social responsibility these information flows should not be processed, used, or stored at any time by the robot. The collection of this data may be considered *'invisible'* to the user, however organisations professing social responsibility should avoid using these type of information flows. Note: Orientation may be any category, e.g. Sexual, Political, Religious, Criminal.

10.4 Social Robot Design Principles

It is through the reflections and learnings from the studies that the design principles for social robot application design have been able to be extracted. The iterative process of designing and implementing social robot applications in different environments, with the

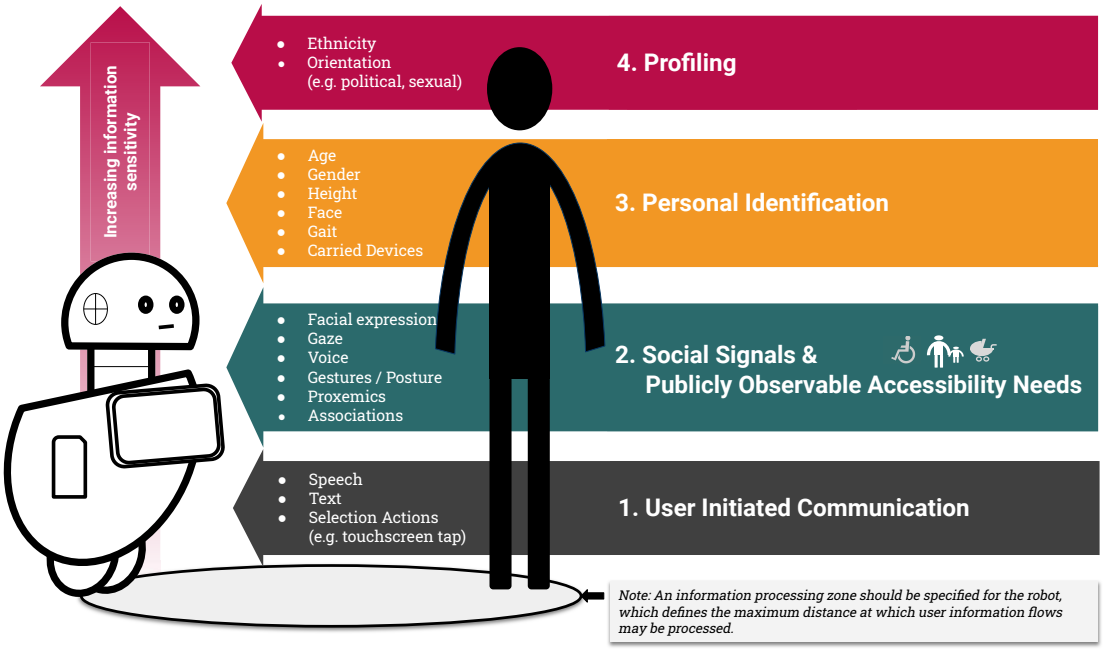


Figure 10.4: Information flow considerations for privacy in social robot application design

point of view of social responsibility, is now used for generalisation across domains. In the Action Design Research process this is accomplished by understanding the developed artifact as a solution that addresses a problem and making a conceptual move from *"specific-and unique to generic-and-abstract"* [346, p. 45].

Each design study artifact was shaped by the people, environment and tools that produced it, yet commonalities emerged. The principles represent general points of direction and require judgement and discretion in their implementation by designers, both researchers and practitioners. It is important that a design principle is sufficiently abstract to allow different instantiations in different contexts. Furthermore, in regard to this research, these principles are understood as the common characteristics that an effective social robot application design for social robots in public spaces should have. Hence they may also be used as a checklist.

The five design principles for social robot application design are defined as follows and presented in Figure 10.5:

1. Authentic Purpose and Representation
2. Reliable and Consistent Functioning
3. Effortless Experience

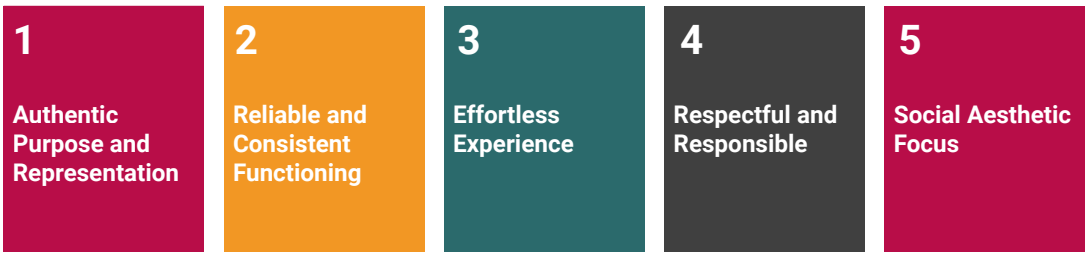


Figure 10.5: Design principles for socially responsible social robot application design

Title: *Design Principle Name*	
Structure	Components
For IMPLEMENTER I to achieve or allow AIM A for USER U	Aim, Implementer and User
In CONTEXT C	Context (Boundary conditions, implementation setting, further user characteristics)
Employ MECHANISMS M1, M2, M3…….involving ENACTORS E E1, E2, E3….	Mechanisms (acts, activities, processes, form / architecture, manipulation of other artifacts) Subsidiary components/artifacts that can have their own design principles
Because of RATIONALE R	Rationale Theoretical or empirical justification for the design principle

Figure 10.6: Design Principle Structure adapted from Gregor *et al.* [153, p. 24]

4. Respectful and Responsible

5. Social Aesthetic Focus

There is inconsistency in ADR literature in how design principles should be specified, however a recent paper by Gregor *et al.* [153] suggests the components as presented in Figure 10.6.

These components have been used as a guide for presenting the social robot application design principles. Differently from Gregor *et al.*, the mechanisms and enactors for each principle are also decomposed into the following three areas specific to HRI: technology, robot, and application. The principles are expanded upon in the following, with explanation and justification as to their derivation.

1. **Authentic Purpose and Representation**
   The aim of this Design principle is for implementers (designers, researchers, organisations) to achieve acceptance and use of the social robot and application by people in a public space (users, bystanders, employees).

   a) **Technology:** 1. Today's technology should be used for development and implementation. This means no Wizard-of-Oz techniques, no robot operator controlling and assisting interactions, no hidden behind-the-scenes human classifying of data.

   b) **Robot:** 1. The robot presents itself without fabrication, without pretense of human experience. 2. The integrity of form, implied by the anthropomorphic shape of the robot, is maintained, i.e. the robot visibly signals its attention via its affordances. For example, if you are behind the robot, it cannot "see" you, unless the physical design of the robot includes "eyes" (or visible cameras), in the back of its head. As such, use of cameras that cannot be easily ascertained by users should be avoided.

   c) **Application:** 1. There is a value the application brings to users, a service based on genuine need. A perceivable benefit to the task the robot is performing. Applications that satisfy a user's unmet needs can be discovered specifically by using the UX-HRI process or other forms of Design Thinking.

   Rationale: Deceiving users regarding performance of the robot should be avoided, as it may be considered unethical marketing behaviour, diminishing trust [238]. Displaying competency in performance will assist in earning trust [391] and trust is seen to be an indicator of acceptance. [142]. Integrity, the quality of being honest, is a core component of trustworthiness. Trustworthiness is known to play a role in acceptance with users [333].

   Furthermore, requiring users to suspend belief, through fabrication that the robot may have lived human experience, optimally should occur only if the situated context and role of the robot warrants it. For example, a social robot pretending to be Snow White and located at Disneyland or a children's musical is warranted due to the environmental context.

   Similarly, obfuscating the robots sensing abilities may be deceiving. Instead, matching form to function and adhering to the implied functionality of the robot given by its anthropomorphic shape and sensor locations will assist to meet Contextual

Integrity (CI) [286]. Additionally, it may be considered an ethical duty [339]. Behaviours and actions avoiding any information collection from unexpected quarters may assist in sending a clear signal of integrity to the user.

Finally, ensuring there is a genuine need to be fulfilled by the robot application avoids the short term use of the robot as a gimmick. This also aids the call for long term studies of human-robot interactions, by providing an ongoing usefulness to persist throughout studies, that will assist with observing novelty effects. The significance of usefulness for increasing social robots acceptance has been demonstrated repeatedly in the HRI literature [96, 115, 116, 119].

2. **Reliable and Consistent Functioning**
   The aim of this Design principle is for implementers (designers, researchers, organisations), primarily commercial organisations, to achieve user satisfaction in the use of the social robot by people in a public space (users, bystanders, employees).

   a) **Technology:** 1. The robot should provide consistent functioning in its service, as much as is possible with today's technology.

   b) **Robot:** 1. There should not be any user interaction dead-ends, the behaviour of the robot should be such that it continually and consistently can assist users, and can recover from error. This may include asking users or bystanders for assistance [241]. 2. Any unexpected malfunctions or lack of capability by the robot should be managed in a graceful degradation or fallback manner.

   c) **Application:** 1. The application must be stand-alone and able to be used again and again by end-users without intervention by a practitioner or researcher, to reset or restart the application after interaction. 2. Any Artificial Intelligence systems used in the application must provide a great enough confidence and accuracy to be able to sensibly guide any decision making required by the robot or by users. 3. There should be no software bugs. Applications should go through comprehensive interaction design and testing with users, as per the UX-HRI process to discover and address any reliability issues.

   Rationale: This design principle came specifically from the act of working with organisations and the assumptions articulated during the design process by the stakeholders. The importance that commercial organisations and public institutions place on reliability was clear. Literature reveals that reliability is considered to be the most important dimension in service quality. It can be defined as the

"ability to perform the promised service dependably and accurately" [298, p. 23]. Reliability is a factor of service quality and a crucial dimension of customer satisfaction, which leads directly to customer loyalty [296].

3. **Effortless Experience**
   The aim of this design principle is for implementers (designers, researchers, organisations), to allow the most effortless experience using the robot by all people in a public space (users, bystanders, employees).

   a) **Technology:** 1. The robot should be able to integrate with the latest technology, support required accessibility options, and connect to surrounding technology. 2. Where possible the robot should automate connecting to organisational services. 3. Appropriate information processing should be used to guide interactions and enable natural, social communication.

   b) **Robot:** 1. The robot should utilise all the advantages that come from its ability to communicate in the physical, social and digital worlds, *Chapter 6*. Communication should be based on the most direct method possible for the given context. 2. The robot morphology, affordances, visual identity, branding, behaviours, actions and personality all play an important role in the interaction. Personality directions for the robot are always along the lines of generosity and helpfulness.

   c) **Application:** 1. The application must be able to be used without human guidance. It has to be designed in such a way that end users can intuitively, or with guidance from the robot, make sense of how to use the application. 2. The application must be designed to be as accessible as possible, with alternative interaction options for a broad spectrum of differing capabilities and needs. 3. The application must not require users to carry a device, download an app to their phone, or any other action that requires more than a simple, physical world interaction, that could be undertaken by a young child. 4. The application should enhance, not hamper, the ability of employees to undertake their work. Scaffolding the design of the interactions with the social robot design space, information flows for social robots, and using Stage Two Design and Build steps of the UX-HRI process, especially role playing, paper prototyping, and continuous user testing, are all mechanisms that will assist with this principle.

Rationale: This principle brings to the fore the importance of the user experience for interaction design with social robots, a concept gaining importance in HRI [8]. It takes the business imperative of reducing customer effort to drive customer loyalty [51] and matches it with the pragmatic factors of usability [184] and the hedonic factors of user experience [163]. It involves designing for inclusivity from the very initial phases of the design process. It acknowledges the peculiarities of the particular context of services provided by a social robot in a public space. That is, robots providing services in public spaces (public services) must be designed to account for the typically short duration of interactions with a very large number of people of varying abilities [21].

4. **Respectful and Responsible**
   The aim of this design principle is for implementers (designers, researchers, organisations), to achieve socially responsible implementations of social robot applications that contribute to the wellbeing of all people in a public space (users, bystanders, employees).

   a) **Technology:** 1. Information processing of information flows should be assessed for privacy impacts. 2. All use of personal information should meet privacy legislation requirements. For example data management practices should comply in Australia with the Australian Privacy Principles. 3. Further and above, personal information collection and processing should be avoided if it involves any profiling of the user. 4. Processing and data collection should remain authentic with the humanoid form: interactions are transient and locally computed where possible. 5. There should be nothing other than summaries or high-level logs that persists unless a user explicitly consents.

   b) **Robot:** 1. The robot will be designed to behave in a manner that is inclusive, respectful and polite, as would be expected for any customer-facing employee of an organisation. This includes gesturing, language (inclusive and positive vocabulary) and tone. 2. Social responsibility is demonstrated in the robots task, actions and behaviour, choice of placement and travel in the intended environment, collection of data and implementation in collaboration with employees. 3. All interactions should be privacy sensitive and appropriate to the situated context. 4. Interactions with the robot are considered as “opt-in”, a user has the choice to chose the option of interacting with the robot. 5. The robot should not be a remotely controlled surveillance system.

c) **Application:** 1. The application does not involve actions or robot behaviors that undercut Human Rights. 2. The application is transparent in its functioning and use of data. The mechanisms by which these can be achieved include considering the Information flows for social robots, (see Chapter 8), the impacts on the seven types of privacy [120], and the International Charter of Human Rights [148].

Rationale: It is generally accepted that social robots have challenges across ethical, legal and societal dimensions [130] and these are quite concerning regarding privacy impacts. By actively designing for robots that respect human rights, through protecting privacy and avoiding surveillance applications (which, is suggested, break social norms) it may contribute to ensuring a sense of ease, or ontological security [144]. Furthermore by proactively creating enjoyable experiences for people to share in a public space, it is possible to set a standard expectation for what social robot application design, and hence future society, could be.

5. **Social Aesthetic Focused**
   The aim of this design principle is for implementers (designers, researchers, organisations), to allow appealing and attractive social robot implementations that beautify the environment and enhance social interactions and inclusion for people in a public place (users, bystanders, employees).

   a) **Technology:** 1. The technology should support the robot to move with grace, agility and appropriate to form. For example, if the robot has human likeness, movement should be as per its anthropomorphic design.

   b) **Robot:** 1. The robot platform chosen for use should be assessed not just on technical merits but on attractiveness and appeal. The robot behaviour should promote inclusiveness.

   c) **Application:** 1. Visual design used in the application should be professional and in a manner that is suitably representative of the organisation. This also includes branding of the robot and tablet screen with a logo and identity.

   Rationale: This design principle came from the necessity of including the visual design of the robot's tablet; importance placed on aesthetics throughout the design studies (both from organisations and observed by researchers); and the realisation that the sociality of the robot is shaped by the people around the robot and the environment it occurs in [178]. Additionally, as social inclusion in public spaces

may be considered important to well-being [60], inclusive design is vital. Social aesthetics can be thought of as the study of art practices and the forms of communication they prompt, specifically involving the study of human social interactions as aesthetic phenomena [39, 73]. At this point in time there is a choice that can be made regarding how future society will look, literally. Social robots and social robot applications do not have to be neutral creations. Choices that support natural, social communication styles, that fit within human-centred environments and promote pleasure and aesthetics in social interaction, may support well being, which meets the social responsibility imperative of today's organisations.

10.4.1 Next Contribution

In the next and final chapter, the summary of contributions are listed, with corresponding limitations, conclusions and possible future work.

CHAPTER 11

CONCLUSIONS

"There is no 'once-and-for-all' solution applicable across HRI" Kerstin Dautenhahn [89, p. 103]

UX-HRI is an experience design framework for HRI that brings together the findings from the studies and research in HRI, with the concepts of human-centred design—comprising Lean UX, Design Thinking and Agile, and Privacy-by-Design, to build social robot applications that are accepted by users, with a viable task and providing a positive contribution to the customer experience.

The framework can be used by researchers or businesses wishing to trial a commercial social robot in their organisation for either research or commercial use in today's society. It allows:

1. Investigation of whether a commercial social robot is a suitable fit for a location

2. Discovery of possible use cases for the robot that meet peoples' needs in that location yet go beyond typical outcomes from ethnography, observation and interview processes.

3. Design and development of a prototype application that provides a good user experience and a seamless integration with the customer experience

4. Implementation of a privacy sensitive and socially responsible application ready for testing or deployment.

11.1 Summary of Contributions

This dissertation has presented a number of findings, including publishing a number of reports (see list of publications), that have extended the HRI field regarding conducting in the wild studies, user experience design and privacy research.

1. In Experiment A: Studies In the Wild—Applications and Challenges, the challenges regarding undertaking studies in the real world were experienced by the research team. It was discovered that a social robot could perform a role requiring social engagement to the same level as a human, albeit with a task that required minimal social interaction. Importantly, the value of identifying applications that were more than just mimicking human tasks was learned. This shaped the perspective with which social robots could be viewed, as more than just social agents, improving on application design possibilities that could be of interest to organisations.

2. In Experiment B: Privacy and its effect on UX in HRI, understanding was gained regarding the necessary privacy considerations for social robot application design. Privacy-by-Design, and specifically transparency in communication, was confirmed as an approach that could be used to ensure meeting privacy legislation. However, careful management would be required to ensure that the sharing of personal information, engendered by the transparent communication of an embodied robot, would be appropriate to the situated context. Hence, a further conceptualisation of privacy would be required. Of great benefit was the finding that the user experience was improved by the robot's transparent communications, signifying an advantage to designing for privacy.

3. Design Study 1: Designing the UX for HRI, took the learnings from the previous experiments, the understandings of business development processes gained from working with a large organisation, and the most recent technology and HRI literature, to trial a social robot at Sydney Airport. The study followed human-centred design with the fledgling UX-HRI process, to discover potential social robot applications that could address an unmet need in the airport environment and improve the customer experience. The study was considered a success by the CBA Innovation

lab and International Airline client management. The learnings from this study included the significance of marketing material to manage people's expectations in the public setting environment.

4. Design Study 2: Designing for privacy in HRI, further refined the UX-HRI process, to include privacy considerations with the collection of sensitive information. The importance of using Contextual Integrity (CI) theory to create an appropriate application design was demonstrated. The additional contribution from this study was the application created, which provided a privacy management system for people using social robots for personal use in public spaces.

5. Design Study 3: Designing with the UX-HRI framework for socially responsible HRI, confirmed the ability of the full UX-HRI framework to be used for HRI studies in a complex and highly privacy sensitive environment, meeting ethics requirements while also providing innovative applications. The importance of understanding the information flows originating from users to the robot and the possible impacts on privacy was solidified. A secondary contribution from this study included the accessible, multi-lingual wayfinding application.

6. Formalising all the learnings from throughout the research, the UX-HRI framework has been generalised for use, allowing organisational deployment of a social robot in public settings. The UX-HRI framework (see Figure 11.1) is provided with components, able to be easily accessed for future use: the social robot design space perspective, social robot design principles, information flow categories and privacy considerations for social robot application design.

11.1.1 Reflexivity

The work undertaken in this research has greatly contributed to my understanding of the social robot application design space, and further strengthened my belief in the importance of social responsibility in social robot application design. The possible impacts of deploying social robots in public spaces without careful management are significant. To ensure a future robot-enabled society that we all can enjoy requires purposeful design and vision.

This work is acknowledged as possible due to the collaboration of multiple researchers, students and the particular organisations for each study. My role in the research evolved from initial technical contributions, to studying potential privacy impacts and design

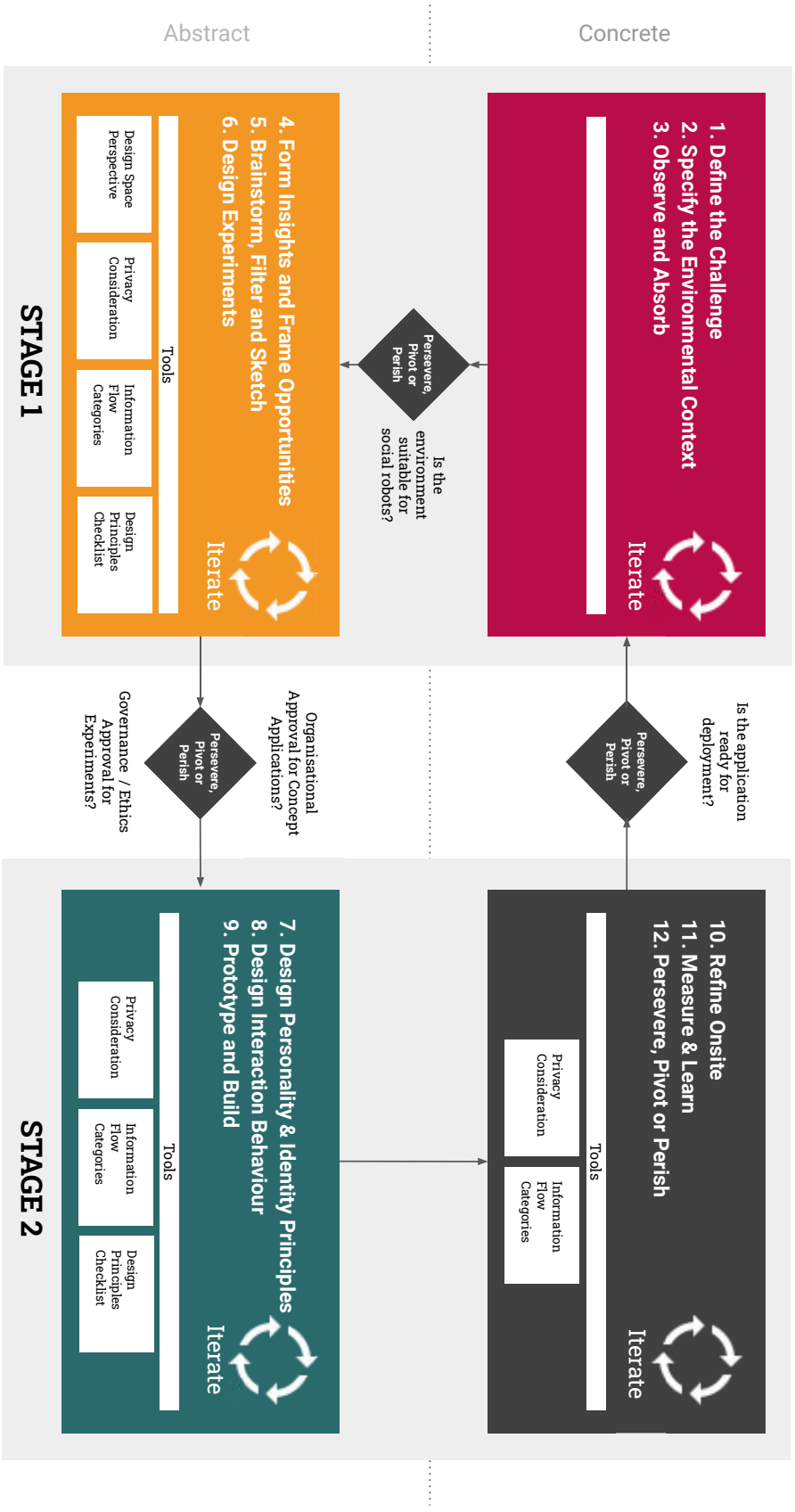


Figure 11.1: The UX-HRI Framework

EXPERIMENT	CONTEXT	MY ROLE	ROLE DESCRIPTION
[Experiment_A] Studies In the Wild - Applications and Challenges	Field - Stockland Shopping Centre	Researcher Facilitator	Identified application to trial and collaborated on experiment design and interaction design with team members. Designed and programmed robot dialog / gestures. Facilitated sign-offs, organisational approvals (Stockland), robot logistics. Onsite experiment researcher and facilitator.
[Experiment_B] Privacy and its effect on UX in HRI	Lab - CBA Innovation Lab	Researcher Interaction Designer	Identified privacy experiment design (realistic risk requirements), collaborated on experiment design with team members. Designed interaction behaviours, dialog and screen displays. Experiment researcher.
[Design Study_1] Designing the UX for HRI	Field - Sydney International Airport	Researcher	Involved throughout the design thinking component of UX-HRI process, design and onsite deployment. No development. Onsite researcher.
[Design Study_2] Designing for Privacy in HRI	Field - Sydney Startup Hub	Researcher Facilitator Interaction Designer	Led all components of the UX-HRI process and privacy design, designed interaction behaviour flows, robot dialogs / gestures, touchscreen display and corresponding website design for mobile and desktop (development by team member). Faciltated organisational requirements. Onsite researcher.
[Design Study_3] Designing with the UX-HRI framework for socially responsible HRI	Field - Fairfield Hospital	Researcher Facilitator Interaction Designer	Led all components of the UX-HRI process and privacy design, designed interaction behaviour flows, robot dialog, video creation. Shared facilitating organisational requirements with team member, onsite researcher and facilitator.

Figure 11.2: Roles in each study

implications, while leading the interaction design, UX, and then guiding with the methodology. This was in contrast to other team members who were interested in technical/algorithmic outcomes, or were interested in the specific findings of the project rather than evaluating the methodology as a whole.

The specific roles I have fulfilled and precise contribution for each experiment and design study are provided in Figure 11.2.

11.1.2 Limitations

Further to the limitations outlined at the end of Chapter 1, there are many areas where this framework could be expanded upon.

The design principles require further detail regarding how to implement the ‘Social Aesthetic’ principle. This is an area for further exploration and may be assisted by investigation into Social Inclusion (SI) design [324] which includes accounting for the role of aesthetic quality in design.

Furthermore, the final design study at the Hospital may have benefited from completion regarding employees’ feedback. This was unable to be collected due to COVID19. However, again, this leaves open the area for further study.

Additionally, the framework requires a commitment to multi-disciplinary teams, able to visit the field and work collaboratively in a time-boxed fashion, with users in the field. Where this type of team is not possible, more traditional design methods may be

required, such as persona development, to assist, and this would have to be assessed for efficacy.

All the studies involved the use of only one robot in an interaction scenario. How the design principles would apply when there are multiple robots, or groups of connected robots, is still to be assessed.

The robots used were mobile humanoid robots, interacting in built, indoor environments. The framework has not been applied to outdoor environments or other robot types, such as social drones or autonomous vehicles, and this is a possible area for extension.

Finally, the framework itself, especially the design principles, is considered as a tool for designing successful robot implementations. The framework has not been used to assess or change existing deployments of robots in public spaces.

11.2 Conclusions

The UX-HRI framework adds to the different design processes available for commercial social robots today. It enables socially responsible design for social robot applications in public spaces, covering the gap in the following areas by:

- Discovering potential social robot applications that address people's needs in shared-use, public environments, with the UX-HRI process and design space perspective. The perspective provides a tri-fold lens through which to envisage potential applications that utilise the full capabilities of the robot across the physical, digital and social realms. It extends the typical outcomes of simple observational (ethnography) or interview processes and unveils novel use cases, which are also beyond those that "mimic" human capability.
- Including user experience design considerations in HRI with the UX-HRI process
- Designing for privacy as an essential element of the UX-HRI process by including privacy considerations and possible information flows from user to social robot in HRI
- Incorporating standard business practices such as UX design and Agile development
- Including design principles that include mechanisms for social robot design and implementation of social robot applications in public spaces

The framework is intended for use by organisations, such as business and government, and academia, and is designed to enable application design that meets the needs of organisations to be socially responsible. By doing so, it has also provided an additional pathway for academics to undertake ethical, real world HRI studies that involve genuine-need applications in partnership with large organisations. As such it is hoped this framework increases the opportunity for establishing socially responsible social robots in society.

11.2.1 Future Work

There have also been many opportunities opened up by this research for future research. For example, the work presented here with the design principles could possibly be used as an assessment tool for already deployed, robotic systems in public spaces. Additional

considerations could be given to outdoor systems such as autonomous vehicles, social drones and agricultural robots. Scenarios such as group-robot interactions could be trialled with the framework. Privacy management systems could be extended in different directions. There are many possibilities waiting to be further researched.

During the final phase of this work, it became apparent that the emerging design principles may actually be sequential. The order of the design principles was not arbitrary. Each of the principles requires the support of the previous and underlying principle. In fact, the order appears to represent the importance of the principles to creating a successful application. Of utmost importance is first establishing the genuine usefulness of the application, design principle one. Without a usefulness, the application may not continue to be used. This has been demonstrated in studies by de Graaf *et al.* [93] and in the real world with Jibo [56]. A useful purpose for the robot is the foundation principle on which all of the rest of the principles rely. Future work will also involve ascertaining if this is, in fact, the case.

APPENDIX A

APPENDIX

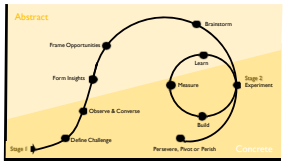
Appendix A: Sydney Startup Hub Document
Provided on the following page is the document presented to the JobsforNSW organisation after the completion of Stage One of the UX-HR process at the Sydney Startup Hub. As can be seen from the storyboards, the proposed applications both involve collection and use of privacy sensitive information, hence the eventual trial application focused on the privacy management system to enable this.



Our process

We combine the best of Design Thinking, Lean UX Start-up, Agile and Human Centered design principles in our unique two-stage methodology.

This enables us to create best fit social robot applications that are designed to be both ethically and socially responsible while also commercially valuable.



Who we are

The Innovation and Enterprise Research Lab (aka The Magic Lab) at University of Technology Sydney is the Southern hemisphere's leading Social Robotics Lab.

Our lab includes academic researchers, PhD students and undergraduate students performing research and development around innovative and disruptive technology, such as Social Robots.

Our aim is to drive innovation for social good and work with industry to undertake research that benefits society.

THE MAGIC LAB

The Challenge

"How might we use Social Robots to enhance the customer experience in the Sydney Startup Hub environment?"



What we do

Our objective is to design viable applications for Social Robots, that can be used in public spaces, such as Sydney Startup Hub.

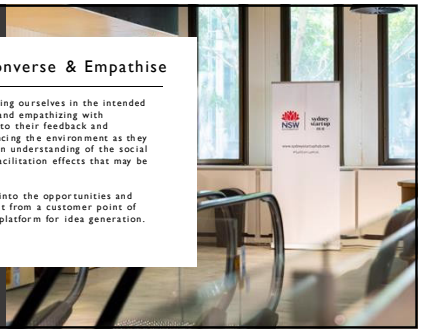
Social robots are one of the true, physical realisations of Artificial Intelligence. Social robots are designed to understand natural human communication and often engage people in a very social and emotional way. In particular, humanoid social robots enhance experiences and bring to life information in a way that other technologies are simply unable to.

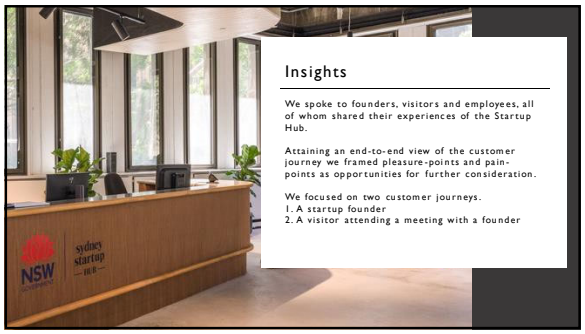
In order to realise the potential and future commercial value social robots may present, we conduct studies to better understand the opportunities and challenges that implementing a social robot application may bring to an environment. This includes exploring technical challenges, such as speech recognition, text-to-speech, computer vision and mapping, and societal challenges, such as user acceptance, user experience, privacy and social impact.

Observe, Converse & Empathise

We began by immersing ourselves in the intended environment of use and empathizing with customers, listening to their feedback and observing, experiencing the environment as they do and allowing us an understanding of the social context and social facilitation effects that may be at play.

This gave us insight into the opportunities and pain-points that exist from a customer point of view and acted as a platform for idea generation.



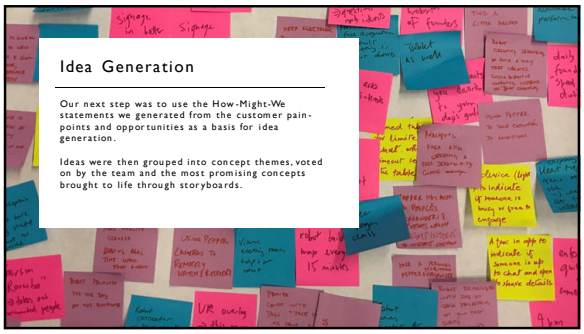


Insights

We spoke to founders, visitors and employees, all of whom shared their experiences of the Startup Hub.

Attaining an end-to-end view of the customer journey we framed pleasure-points and pain-points as opportunities for further consideration.

We focused on two customer journeys.
1. A startup founder
2. A visitor attending a meeting with a founder



Idea Generation

Our next step was to use the How-Might-We statements we generated from the customer pain-points and opportunities as a basis for idea generation.

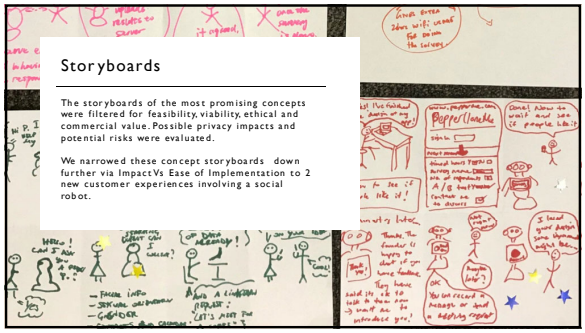
Ideas were then grouped into concept themes, voted on by the team and the most promising concepts brought to life through storyboards.

Level 1 Founder End-to-End Journey

	Arrive	Investigate	Work	Meet	Exit
Activity	• Arrive at StartUp Hub	• Look for suitable desk to work at	• Conduct Startup work • –Headphones on to avoid distraction	• –Coffee • Meet clients/ fellow startup founders and chat • –Move to meeting room	• Leave StartUp Hub
Emotion					
Insight		Founders feel a sense of serendipity due to the chance human interactions afforded by the space	Founders want to work without distraction but still socialise, connect with and get feedback from others	Founders want to be able to use the space freely without having to pre-book meeting rooms or sibling	

How might we increase the serendipity at StartUp Hub yet also allow work to be performed uninterrupted?

How might we provide visibility to founders as to who is doing what and where?



Storyboards

The storyboards of the most promising concepts were filtered for feasibility, viability, ethical and commercial value. Possible privacy impacts and potential risks were evaluated.

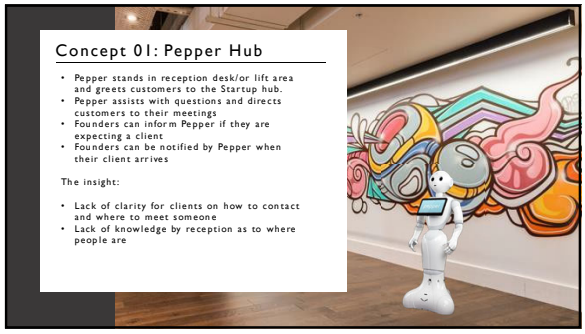
We narrowed these concept storyboards down further via Impact Vs Ease of Implementation to 2 new customer experiences involving a social robot.

Client Meeting End-to-End Journey

	Arrive	Investigate	Wait	Meet	Exit
Activity	• Arrive at StartUp Hub • Look for signage or someone to help • Observe people in environment	• Walk around or stand to side whilst trying to understand where to go • Speak to Receptionists • Inquire how to contact person required	• Contact person, if possible • Wait for person required	• Meet with person • –Order Coffee • Move to meeting room	• Farewell person • Leave StartUp Hub
Emotion					
Insight	Signage or other information in the space is opaque	Lack of clarity on how to contact and where to meet someone causes default "askreceptionist" behaviour	Lack of knowledge by reception as to who people are or meetings occurring		

How might we create clarity for clients meeting at the StartUp Hub?

How might we provide visibility to reception as to who is doing what and where?



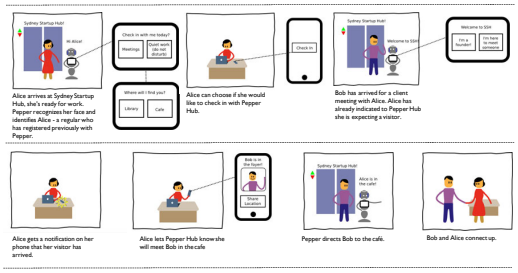
Concept 01: Pepper Hub

- Pepper stands in reception desk/or lift area and greets customers to the Startup hub.
- Pepper assists with questions and directs customers to their meetings
- Founders can inform Pepper if they are expecting a client
- Founders can be notified by Pepper when their client arrives

The insight:

- Lack of clarity for clients on how to contact and where to meet someone
- Lack of knowledge by reception as to where people are

Pepper Hub Storyboard



Next Steps

- Confirmation by Startup Hub NSW required to go ahead with the 2 trial concept applications
- Ethics approval by UTS of trial applications research
- Prototype build and design of the 2 applications

Concept 02: Founder Feedback

- Pepper works for founders by conducting surveys.
- Founders upload their survey questions and required demographics to Pepper Hub's website.
- Pepper surveys customers to Startup Hub, providing real time feedback to founders on their surveys.
- Interested customers can choose to meet with the founder to provide further feedback/ideas.

The insight:

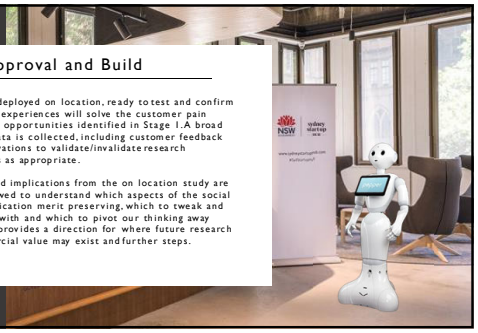
- Founders want to work undistracted but also connect with and get feedback from others in the space.



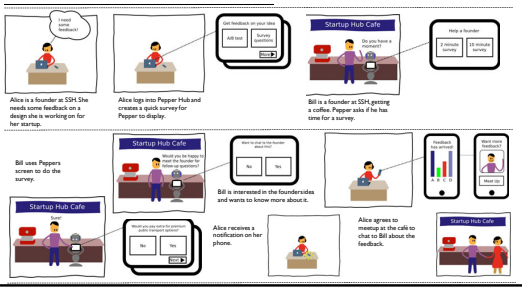
Post Approval and Build

Pepper is deployed on location, ready to test and confirm if the new experiences will solve the customer pain points and opportunities identified in Stage 1.A broad array of data is collected, including customer feedback and observations to validate/invalidate research hypotheses as appropriate.

Insights and implications from the on location study are then reviewed to understand which aspects of the social robot application merit preserving, which to tweak and persevere with and which to pivot our thinking away from.This provides a direction for where future research or commercial value may exist and further steps.



Founder Feedback Storyboard



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