Applying the “human-dog interaction” metaphor in human-robot interaction: a co-design practice engaging healthy retired adults in China

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Abstract

This research adopts a Deweyan pragmatist approach and "research *through* design" methods to explore the use of human-dog interaction as a model for developing human-robot interaction. This research asks two questions: (1) In what way could the human-dog interaction model inform the design of social robots to meet the needs of older adults? (2) What role could aesthetic, functional and behavioural aspects of the human-dog interaction play in older adults' interaction with social robots?

Driven by the pragmatist approach, this thesis uses the dog-human interaction model as a metaphor in this thesis. The research carried out four studies in two parts. The first part of the practice includes two explorative studies to identify aspects of human-dog interaction that could inform the design of social robots for older adults. Study 1 explores aspects of human-dog interaction that could inform the design of human-robot interaction for retired adults. Study 2 explores a group of healthy retired adults' attitudes and preferences toward social/assistive robots in China. The findings suggest that, first, the pairing and training process provides a framework for building personalised social robots in terms of form, function, interaction, and stakeholders involved. Second, the cooperative interaction between a human and a guide dog provides insights for building social robots that take on leading roles in interactions. The robot-as-dog metaphor offers a new perspective to rethink the design process of social robots based on the role dog trainer, owner, and the dog plays in human-dog interaction.

In the second part of the practice, two more studies are conducted to articulate the usefulness of the designer-as-trainer-metaphor, and the personalisation-as-training-metaphor, using participatory co-designing methods. Engaging both retired adult participants and roboticists as co-designers to investigate further how aesthetic aspects, functional features, and interactive behaviours characterising dog-human interaction could inform how older adults can interact with social robots. Study 3 involved co-designing a robot probe with roboticists and later deploying it in a participant's home using the Wizard of Oz method. The personalisation-as-training metaphor helps facilitate a critical discussion for the interdisciplinary co-design process. It broadens the design space when addressing the technical limitation of the probe's camera through reflection-in-action. Study 4 engages the retired adults as co-designers to envision what characteristics they would like robots to have, with

attention to the robot's form, the functions that the robot can perform and how the robot interacts with users. The study applies techniques such as sketching and storyboarding to understand how retired adults make sense of these core elements that are key to developing social/assistive robots for positive ageing.

This thesis makes two main contributions to knowledge in human-robot interaction and interaction design research. Firstly, it provides an applied example using the robot-as-dog metaphor as a tool to probe human-robot interactions in a domestic context. Secondly, to show dog-human interaction model is applicable to different levels of abstraction for the co-designing process that involves the roboticists and the end-users. The outcome shows a reflective practice that engages metaphors to facilitate communication across disciplines in the co-design process.

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Glossary

1. Co-design

All studies in this research involved participants. The co-design is criticised for implying that designers are becoming more important than other participants. Therefore, co-creation is gaining more attention to encourage an equal emphasis on participants and designers. In this thesis, considering the conventional emphasis on robotic engineering and computer science, co-design is used to highlight the potential role of design in study 3. It is to be noted that in Study 4, participants are treated as co-creators.

2. Dyad

Dyad comes from the Greek word 'duad', meaning the number two. A dyad refers to a pair of individuals in an interactional situation. In this thesis, the human-dog dyad emphasises the interactions between one person and one dog.

3. Human-dog interaction

This research reviewed a number of relevant subject areas of human-dog interaction, which studied dogs as a species, including the evolution history of dogs, domestication of dogs, ethology, and dog training techniques. These subjects are discussed in different sections of the thesis separately. However, in this research's practice component, human-dog interaction focuses on the interactions between a specific person and a specific dog.

4. Retired adults (and older adults)

In this thesis, older adults are seen as a heterogeneous group of people. Instead of approaching this large demographic by an age range only, I take on a perspective that sees getting old as part of the human experience. Retirement is a turning point for adults and narrows down the participants in this research to retired adults. In the thesis, older adults indicate the broader body of research that focuses on robots developed for older adults.

5. Roboticists

In this research, roboticists are researchers or professionals trained in robotic engineering and computer science that focus on the actual construction of a robot. In other words, the roboticists deal with the question of making a robot right and tend to focus on technical opportunities in the development process.

6. Metaphor

The concept of metaphor is mainly inspired by Donald Schön's work on the role of generative metaphor in the pump-paintbrush example. In addition, George Lakoff's theory of metaphor also influenced this research. He suggests metaphors as a matter of thought that shape the way we think, which is consistent with Schön's use of metaphor in problem setting.

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Thanks to everyone!

Author’s Declaration

This thesis represents partial submission for the degree of Doctor of Philosophy/ Master of Philosophy at the Royal College of Art. I confirm that the work presented here is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

During the period of registered study in which this thesis was prepared the author has not been registered for any other academic award or qualification. The material included in this thesis has not been submitted wholly or in part for any academic award or qualification other than that for which it is now submitted.

Chenyi Liao

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Contents

1 Introduction

1.1 Background

A growing number of consumer products are emerging, ranging from voice-activated appliances to social robots that are establishing new forms of interaction. Donald Norman (2005) argues that "people adapt to the tools" instead of tools adapting to people, by giving examples of how people learn to use writing systems and adapt to driving automobiles. This raises the question of what the implications are of users learning to use and adapting to an emerging breed of artificial agents that are endowed with social behaviours, physical embodiment and learning abilities. How might we design robotic agents to interact with humans in everyday environments and situations?

In the early 2000s, the field of human-computer interaction (HCI) started to focus on consumer products designed for everyday life beyond rationality, work, and productivity. This shift is called the Third Wave in HCI. It has influenced the field of human-robot interaction as an increasing number of robotic systems were developed into consumer products and entered the domestic environment (Bødker, 2015). Robots, as hybrid systems, utilise the advantages of both physical presence and their ability to embody social behaviours.

World population ageing is accelerating. It is projected that the number of older adults will reach 1.5 billion by 2050 (United Nations, 2019, p.12). China's population is ageing rapidly, and older adults demand affordable healthcare solutions (Jiang et al., 2016). The development of robots for eldercare is driven by technological advancement in China, focusing on addressing physical disability and illness of older adults; therefore, existing research is dominated by an interest in assistive robots for rehabilitation and mobility assistance. On the other hand, socially assistive robots (SARs) can complement assistive robotics by providing older adults with psychological and social support. While China has deployed SARs in hospitals, the USA has utilised SARs across hospitals, private homes, and occupational health centres. Europe and the USA started research on robots for older adults in the 1970s and 1980s, whereas China's development in eldercare robots was still in infancy (Zhang et al., 2016). Following the Chinese government's notice to allocate resources to the healthcare system and the robotic industry in 2017, a unified strategy for developing robots for eldercare is yet to be established.

1.2 Motivation

This research originates from my personal experience, being the only child of my family and my background in communication design. Since implementing the One-Child Policy in the 1980s, China's declining birth rates and extended life expectancy have contributed to a foreseeable shortage of human labour (Ling et al., 2021). Robots are likely to play a role in eldercare to assist eldercare (Thang and Yeung, 2018). Robots are imagined and familiarised through portraits in science fiction and films. Yet, only robotic vacuum cleaners successfully entered the homes of many, while other social robots failed to find their places in the domestic environment. Throughout the history of robots, robotic dogs were invented, suggesting a desire for creating new kinds of 'significant otherness' that humans live with. Dogs are also used as a model for future robots by researchers in human-robot interaction and design research. This is reviewed in the next chapter.

"Research *through* Design" methods is gaining ground in the field of HRI (Luria et al., 2019). Designers dealing with the question of robots entering the domestic environment propose alternative approaches to understand those new interactions. For example, an ecological approach frames robots as consumer products positioned in an ecology with users and other agents in a domestic environment (Forlizzi, DiSalvo and Gemperle, 2004). James Auger (2014), a speculative design practitioner, explores through his work the reasons why robots have not entered the domestic environment. He adopts a Speculative Design approach to seek insights into the possible ways robots could become household products. In pursuing a conceptual framework for thinking about human-robot interaction, human-dog interactions offer a model for thinking about and designing human-robot interaction, providing three general points of reflection: (1) the domestication of canines is a reciprocal process between humans and dogs; (2) the roles of humans and dogs shifted throughout their time living and working together, from hunting with humans in the past, to pet dogs, assistance dogs, and service dogs; (3) the diverse roles dogs play in human activities are the outcome of the interspecies interactions between human and canine species under specific circumstances and time. Given the continuous relationship between dogs and humans and their cooperation in a wide range of scenarios, including niche professions, characterised by an asymmetrical relation in which humans take control, understanding the mechanism of canine social interactions with humans could provide insights into the development of robotic agents.

1.3 Research Questions

Based on the reflections above, two main questions form the basis for this inquiry:

1. How could and in what way the human-dog interaction model inform the design of social robots to meet the needs of older adults?

2. What role could the aesthetic, functional and behavioural aspects of the human-dog interaction play in older adults' interaction with social robots?

1.4 Methodological Approach

Overall, this thesis follows a pragmatist approach to tread the methodological challenges, and tensions found when a "research *through* design" paradigm is applied within the field of human-robot interaction. Engaging metaphor, ethics, and co-design reflect the epistemological and methodological commitments tied to the pragmatist approach to answering the research questions.

1.5 Contribution

This thesis makes two main contributions to knowledge in the field of human-robot interaction and interaction design research. Firstly, it provides an applied example using the robot-as-dog metaphor as a tool to probe human-robot interactions in a domestic context. By comparing the findings of the source domain (human-dog interaction) and the target domain (human-robot interaction), the research identified the importance of personalisation. In the case of human-dog interaction, a human handler and their dog achieve this mutual relationship through training. In human-robot interaction, this level of personalisation is desired for creating personal robots that are useful, meaningful, and adaptable to changes. In the attempt to apply the role of a dog trainer to human-robot interaction, the research established the need to engage design research to support a similar training process for personalisation.

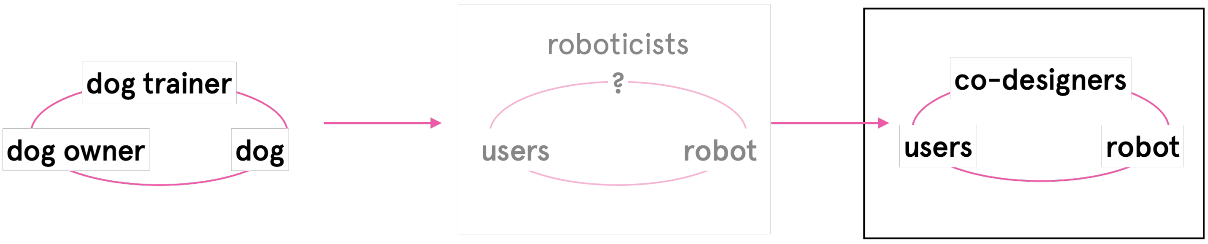


Figure 1-1 Designer-as-trainer metaphor

Secondly, to show dog-human interaction model is applicable to different levels of abstraction for the co-designing process that involves the roboticists and the end-users. This research positioned the role of designer-as-trainer in a co-design process which applied the personalisation-as-training metaphor in the co-design process for developing personalised robots. The outcome shows a reflective practice that engages metaphors to facilitate communication across disciplines in the co-design process.

1.6 Structure

This thesis is structured into eight chapters. Following Chapter 1, the introduction, and relevant works grounded in three disciplines are reviewed in Chapter 2. Chapter 3 explains the methodological approach adopted in this research and how the approach is manifested in my practice. The practice is divided into two parts, situated in the field of interaction design and using communication and participatory design methods. Part 1 includes two studies (Chapter 4 and 5) where I examined aspects of the human-dog interaction model and the needs of healthy older adults in China, respectively. Part 2 is based on the findings and reflections made in Part 1, which led to two more studies, Study 3 and 4 (detailed in Chapters 6 and 7). Study 3 focuses on the generative potential of metaphor and its implications by reflecting on a multidiscipline co-design process. Study 4 explores the role of aesthetics, functional features and interactional aspect of human-dog interaction that are also at play in human-robot interaction with retired adults as co-designers. The last chapter concludes the findings and articulates the contributions of this thesis.

The following diagram (figure 1-1) shows the journey of this research. It shows how I came to arrive at metaphor as an analytical tool for understanding the diverse work grounded in different disciplines after first-hand observations of human-dog interaction. The following chapter explains how the work grounded in different disciplines could also benefit from a unified framework. Then, I introduce the relevant contextual review, which evolved after conducting observations of human-dog interactions in the first study.

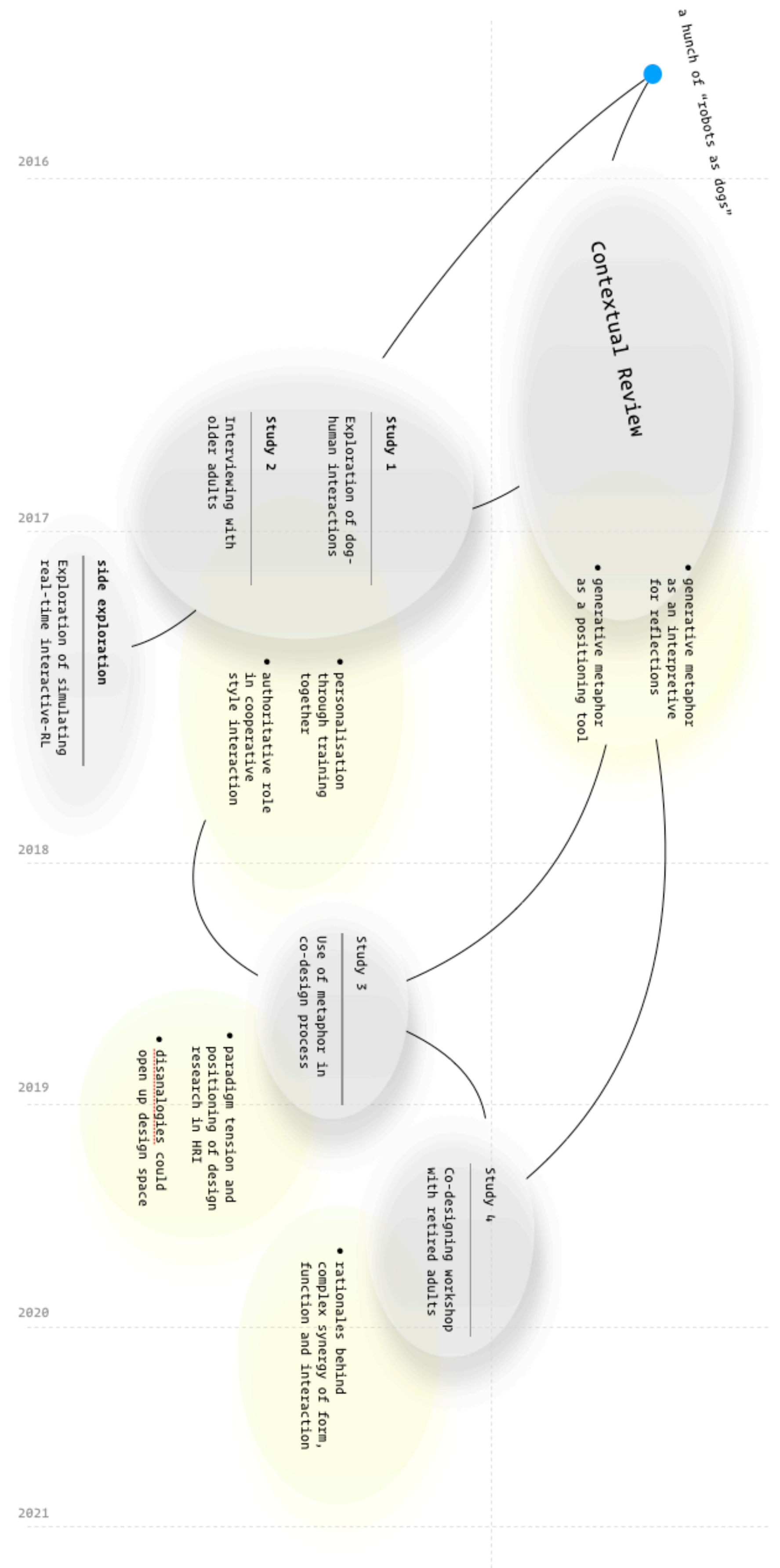


Figure 1-2 Research journey map.

2 Contextual Review

2.1 Robots and Dogs

2.1.1 Definition of robots

The word robot came from Czech writer Karel Čapek's play Rossum's Universal Robots, first performed in the early 1920s. The term Robot was used to describe the artificial humans that work as cheap labour in the play. Since then, many robots have been created in films, science fiction, and real life. It is challenging to give a universal definition of robots. However, robots created for manufacturing purposes that reflect the robot's original connotation are already in contemporary life, known as industrial robots.

> An industrial robot is defined to be an automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications. (International Federation of Robotics, 2012).

The International Federation of Robotics (IFR) divides robots into two categories, industrial and service robots. While the definition of industrial robots gives a relatively clear idea of the functions, technologies and contexts of use, the definition of service robots remains broad.

> A service robot is a robot that performs useful tasks for humans or equipment excluding industrial automation applications. (International Federation of Robotics, 2012).

Following the definition given by IFR above, robots developed for older adults are categorised as service robots. More accurately, Broekens, Heerink and Rosendal (2009, p.95) categorised three types of assistive robots for older adults (figure 2-1), including assistive robots that focus on rehabilitation, and assistive social robots which provide service or companionship.

Figure redacted for copyright regulations, please find the image from: Broekens, J., Heerink, M., & Rosendal, H. (2009). Assistive social robots in elderly care: A review. Gerontechnology, 8(2), 94–103. https://doi.org/10.4017/gt.2009.08.02.002.00

Figure 2-1 Categorisation by Broekens, Heerink and Rosendal (2009, p.95)

This categorisation is widely accepted in Human-Robot Interaction. In more recent years, socially assistive robots emerged as a new category of robots that aims to 'give assistance through social interaction' (Bemelmans et al., 2012).

2.1.2 (Messy) categorisation of robots

Current categorisations divide robots into assistive robots, assistive social robots, and socially assistive robots. Assistive robots provide physical assistance to older adults, which also implies a form that is object-like or focuses on maximising robots' dedicated functions. Assistive social robots and socially assistive robots are usually endowed with zoomorphic or anthropomorphic features. However, the wide range of functions and forms that make up socially assistive robots and assistive social robots leaves the definition unclear (Kachouie et al., 2014). For example, Hobbit, a care robot that offers fall prevention, emergency detection, reminders, and entertainment functions can be categorised as either an assistive social robot or a socially assistive robot (Fischinger et al., 2014). Sometimes, these terms are used interchangeably, though, in recent years, socially assistive robots have gained more recognition in academic research. It is better to understand socially assistive robots through the two aspects socially assistive robots aim to leverage: first, the human brain responds to physically present agents like robots more strongly than it does to virtual agents; second, humans are social animals who are influenced by social factors (Abbasi, 2017). Understanding these two aspects is more useful when considering the strengths and space for design in this category of robots. Companion robots also act as an umbrella term for robots of many roles, namely assistant, friend, or butler (Dautenhahn et al., 2005). Many companion robots have zoomorphic features in their appearance. Miklósi and Gácsi (2012) argue that all social robots should be seen as companion robots and emphasise the interspecific interaction between humans and social robots.

This section does not intend to find a universal categorisation of all robots, but rather to highlight the diversity of robots and a range of robotic objects and agents outside the conventional functions and forms that do not fit into any of the three major categories. Robots are man-made artefacts, what Hebert Simon (1970) calls "artificial phenomena" (p.113). The robots are artificial in a specific sense as they are contingent to the environment they are made in. To understand how categorisations of robots could hinder the imagination of alternative robots, I propose a new diagram to position and show the similarities of different types of robots according to the dimension of form, function, and interaction style (figure 2-2).

The previous categorisation of robotic devices for older adults separates rehabilitation robots from assistive social robots (Broekens, Heerink and Rosendal, 2009), and the latter includes service robots and companion robots (Sim and Loo, 2015). The 2-dimensional chart style visualisation of the categorisation suggests a clear division among the subcategories of robots. However, these robots' functional features and appearance features often overlap. The 3-dimensional diagram below shows three axes relevant to a robot's design, in terms of its appearance, function, and interaction style. The green axis shows the appearance dimension of the robot, from object-like to zoomorphic, then human-like. The blue axis shows the function dimension of the robot, from open to defined. The red axis shows the interaction style dimension, ranging from task-oriented to play-oriented.

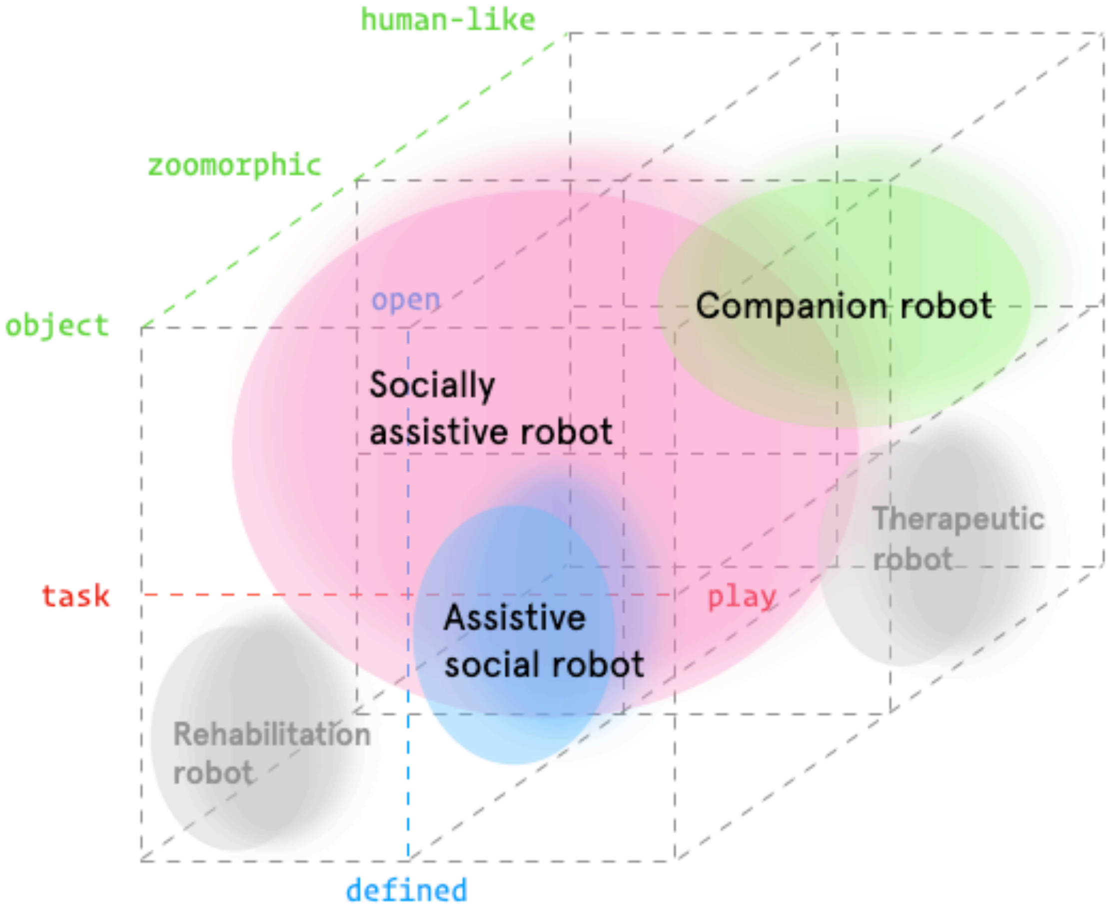


Figure 2-2 Proposed visualization of the categories of service robots.

In this diagram, the division among the subcategories of robots is overlapped. Each category is shown with a shape to highlight the overlapping and different spaces each category of robots occupies. For example, socially assistive robots overlap with companion robots, assistive social robots and therapeutic robots. Companion robots often have zoomorphic features (e.g. AIBO) for their appearance, which is sometimes found in socially assistive robots. However, these two categories of robots divert in the dimension of their function and interaction aspects, whereas companion robots have relatively open-ended functions, and play-oriented interactions. This diagram allows individual robot designs that were previously under the same category to be positioned in accordance with the three dimensions of robot designs. Moreover, the white space in this diagram shows the other possible spaces for robots that are hard to categorise and considers future robots that are yet to be invented.

2.1.3 Robotic dogs in HRI

To illustrate the necessity of leaving the definition of service robot broad, robotic dogs created throughout the history of robotics are provided as examples; from

Sparko, designed by Don Lee Hadley in the 1940s, to AIBO (aibō in Japanese, means 'pal') by Sony in 1990s, and quadruped robots by Boston Dynamics in 2010s. These robotic creatures are imagined by their creators to live with humans and work with as social robots, companion robots, or service robots. Created in 2020 by Boston Dynamics, Spot is a four-legged robot dog with unprecedented mobility and agility. Spot became an internet sensation as a telepresence-based extension at Brigham and Women's Hospital in Massachusetts, where the robot was remotely helping medical staff to treat coronavirus patients during the pandemic (Ackerman, 2020).

Figure redacted for copyright regulations, please find the image at: http://cyberneticzoo.com/robots/1940-sparko-the-robot-dog-american/

Figure 2-3 Sparko by Don Lee Hadley, 1940. (Cyberne, 2009)

Figure redacted for copyright regulations, please find the image at: https://www.sony.com/en/SonyInfo/CorporateInfo/History/sonyhistory-j.html

Figure 2-4 ERS-100 by Sony Group, first-generation "AIBO", 1999. (Sony Group Portal, 2022)

Figure redacted for copyright regulations, please find the image from: Wakefield, J. (2019) 'Boston Dynamics robot dog Spot goes on sale', 25 September. Available at: https://www.bbc.co.uk/news/technology-49823945 (Accessed: 16 August 2022).

Figure 2-5 SPOT by Boston Dynamics, first commercially available robot. (Wakefield, 2019).

The domestication history of dogs tells a fascinating story of a wild animal that now lives with and serves the humans. These robots are imagined and designed as a new species similar to domestic dogs that also could be companions or workers in human society. This sparked the question in my research as to whether robots can one day, become a 'significant other' for humans the way dogs have. The possibilities for human-dog interaction provide an attractive source for imagining the future with robots. The following sections explain Auger's, Dautenhan's, and Miklósi's rationales behind seeing dogs today as robots for the future, and how their arguments contribute to human-robot interaction.

2.2 Robot-as-dog Metaphor

2.2.1 Dautenhahn's developmental perspective

Inspired by domestic dogs, Dautenhahn (2004, p.21) proposed a developmental model of personalised companion robots that people might live in their domestic environments. Taking inspiration from the socialisation phase of domestic dogs, Dautenhahn's developmental model involves three phases (Figure 2-6).

Figure redacted for copyright regulations, please find the diagram from: Dautenhahn, K. (2004) ‘Robots we like to live with?! - a developmental perspective on a personalized, life-long robot companion’, in ROMAN-04. RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication, IEEE, pp. 17–22. doi:10.1109/ROMAN.2004.1374720.

Figure 2-6 Dautenhahn’s three-phased developmental model of personalised robot companions (2004, p.21).

In her proposed model, Dautenhahn suggests that robots could go through a socialisation phase in the laboratory, where the default behavioural settings for individual robots could be embedded into the robot, and then the robot could enter the next phase of personalisation, where the robot learns through interactions at home. The underlying idea is that robots are developed towards taking on the perceived role of an individual personalised companion which is designed to live with a person. Dautenhahn recognises the limitation of the range of tasks, environments and interactions that could be planned based on the profiles of tasks, environments and users gathered from human-robot interaction studies. Therefore, the last phase of the model allows the robot to change profiles based on interaction histories through adaptation and social learning in home settings.

2.2.2 Dogs as a model for social robots by Miklósi

Similar to Dautenhahn’s inquiry on building companion robots, researchers in ethology also argue that human-dog companionship provides insights for engineering robot companions (Lakatos and Miklósi, 2012). The human-human model emphasises facial expressions and verbal communication skills in humans.

Highly human-like appearance and behaviour are extremely challenging to engineer, and raise user expectations about a robot's capability and performance, which at times result in frustration and disappointment. Driven by the technical difficulties and ethical considerations of building human-like robots, Miklósi et al. (2017) propose that the human-dog model is better than the human-human model for building social robots.

Ethology is the study of animal behaviours as found within their natural habitat. Gácsi et al. (2009) point out the difference between taming and domestication: taming is only applicable to an individual animal's lifetime; the changes are epigenetic, whereas domestication is an evolutionary process involving humans selection and alters the genetics of a group of animals. While ethologists recognise the importance of learning in shaping behaviours, an emphasis is placed on an evolutionary aspect that focuses on innate behaviours and is performed instinctively as a strategy to increase the rate of survival. From an ethological perspective, social behaviour serves a survival function. Domesticated dogs developed skills to act optimally (from their own point of view) in dyadic relationships in which they are involved in human society (Miklósi, 2009, p.224). Researchers studied human-dog communication by conducting comparative studies between domesticated dogs and intensively socialised wolves, and suggest that the domestication process allows dogs to develop skills in reading human gestures at a younger age (Lakatos and Miklósi, 2012). Assistant dogs' communicative behaviours and problem-solving strategies are also found useful in developing similar functions of assistant robots (Faragó et al., 2014). The interaction between humans and dogs is a form of interspecies communication developed through co-evolution. Considering that humans and robots could be seen as two separate species, the human-dog interaction model has irreplaceable advantages over the human-human interaction model in human-robot interaction (Miklósi and Gácsi, 2012).

Beyond the fruitful insights of dogs' social skills and behaviours, Miklósi and others propose an ethological approach to the development of the human-robot relationship and which they claim provides a more plausible theoretical foundation for social robotics. This is a bottom-up approach for roboticists to 'construct robots that are able to maximise their performance in their niche (being optimal for some specific functions), and if they are endowed with the appropriate form of social competence, then humans will eventually interact with them independent of their embodiment' (Miklósi et al., 2017). The key offered by the bottom-up approach is to acknowledge that a good human-robot relationship is achieved through appropriate social interactions between humans and robots, instead of an "a priori attribute" of robots. The emergence of certain partnerships depends on social competence and the amount of time spent on social interactions. In other words, Miklósi et al. (2017) suggest developing the function of social robots away from those similar to humans, and the robots' embodiment, behaviour, and problem-solving skills should be determined by their specific environments. While dogs achieved the social partner role of companions, researchers envision a new generation of social robots, ethorobots, that show basic social skills found in dogs; for example, dogs' attachment behaviour (Gácsi, Szakadat and Miklósi, 2012), simple communicative skills (Polgárdi et al., 2000), responsiveness to training (Gácsi et al., 2009), and being useful in cooperative problem-solving tasks with human partners (Ostojić and Clayton, 2014).

A number of studies focused on the interspecific nature of human-dog interactions. Dogs play with humans. Their playful interactions with humans are motivated differently from dog-dog play and involve a different structure (Rooney et al., 2001). During cooperative interactions, both humans' and dogs' behaviour are organised into what Kerepesi et al. (2005) call interactive temporal patterns which play a functional role in cooperative human-dog interaction. The ability to engage in temporally structured interaction with humans is a crucial differentiator to set human-dog interaction apart from human-AIBO interaction.

Many studies (such as Hiby, Rooney and Bradshaw, 2004; Jamieson et al., 2017; MacLean and Hare, 2018) focus on determining biological features of dog breeds and particular dogs to identify their suitability to be trained as working dogs. Dogs' genetic qualities play a significant part in the types of work they do with humans (MacLean and Hare, 2018). Historically, dogs demonstrated an ability to cooperate with humans that was enhanced by selective breeding during domestication and that could be built upon through training (Naderi et al., 2002). In a recent study of human-dog communication, Range et al. (2019) compared how dogs and wolves cooperated with human partners in a string-pully task. They found that dogs were more likely to wait for humans to initiate actions, and suggested that dogs are selected for submissive inclinations to humans during the domestication to ensure safe living with humans.

In complement to Dautenhahn's reference to the socialization phase in domestic dogs, Miklósi et al. (2017) extracted behaviours and social skills from empirical studies of interactions between dogs and humans. They suggested that all social robots could benefit from such social competence. Their proposal of ethorobots is underpinned by the robot-as-dog metaphor, which indicates that future robots could go through a domestication process akin to the domestication of dogs, and will lead to benefits for both humans and robots.

2.2.3 Domestication and post-utility status by Auger

By seeing future robots as domestic dogs today, Auger compared the domestication of technology to the evolution of dogs, and made critical reflections based on the metaphor robots-as-dogs. Auger (2012, pp.105-106) pointed out that domestic dogs are products which have gone through a (deliberate) domestication process. Wolves changed in terms of form, function, behaviour and modes of interaction, and eventually became the dogs that entered humans' lives and their existence became centred around humans. Comparing dogs to another product that has successfully entered human society, personal computers, led Auger to explore formal, functional and interaction adaptations that could turn technology into robot products. Based on the successful adaptations of dogs and personal computers, Auger (2012, p. 85) suggested that robots need to excel at their underlying technology, yet the 'complex sensing techniques, the information storing and processing, and repetitive, continuous and autonomous movement' of robots are in contrary to the home environment that is warm and idiosyncratic. Auger (2012, pp 45–46) saw the cause of technologies that failed to become products as maladaptations, and specified the concerns over the implications of pervasive robotic technologies on 'domestic life and emotional interaction and human communications'.

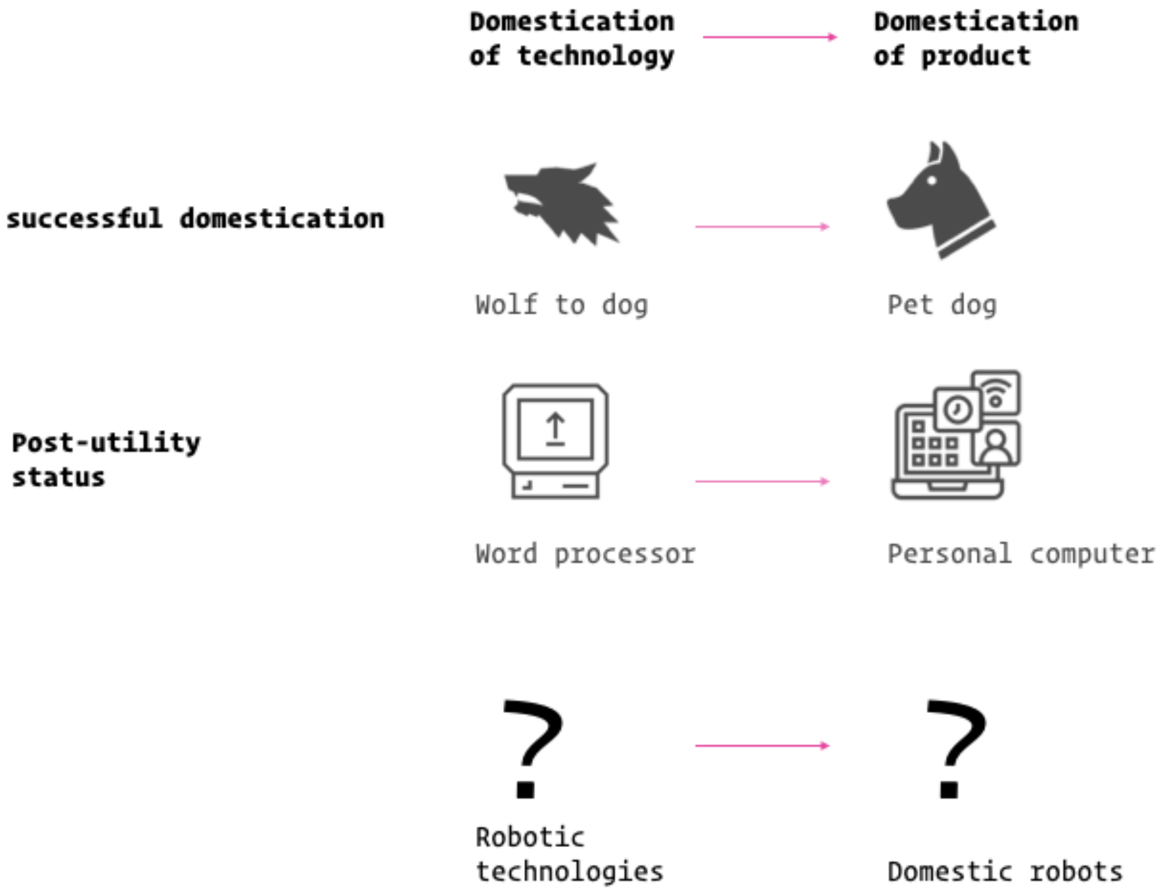


Figure 2-7 Auger's analysis of dogs and personal computers as successful domesticated products, and how they achieved a post-utility status.

Auger discussed the post-utility status achieved by dogs and computers. He argued that humans kept dogs at home for emotional value as pet dogs, instead of utilitarian functions. The post-utility status of dogs cannot and should not be the goal for robots. Giving the example of the well-funded research in care robots for elder care and the remaining questions of whether it is ethical to outsource eldercare to robots, Auger (2012, pp. 65–66) criticised the trend of "robots in search of a problem" and pointed out that roboticists tend to replicate the existing niche of domestic dogs as a companion robot. In recent years, ethical questions about robots for eldercare have been a research field of its own right. Many more researchers explored how robots contribute to the care work rather than simply replace the work of humans (Haring, Watanabe and Mougenot, 2013; Breazeal, 2003). Auger (2012) also discussed the post-utility status of personal computers, which was achieved by "the scope of possibility facilitated by its software and content" (p.124). He warns about the importance of addressing the fundamental question of why we should develop domestic robots in the first place, apart from developments in robot interactions and usability.

In short, the robot-as-dog metaphor is a thinking tool for Auger, Dautenhahn, Miklósi and others. The metaphor produced useful reflections and conclusions for the development of domestic robots, service robots, and social robots.

2.3 Assistive Robotics for Older Adults

2.3.1 Assistive robots and underlying approach to ageing

A range of robotic technologies and assistive robots have been developed to support older adults, including nursing robots, ambient assisted living, telerobotics, and assistive robots (Chirstoforou et al., 2020). Examples include multifunctional assistive robots like Care-O-Bot (Kittmann et al., 2015), MOBISERV (van den Heuvel, 2013) and Hobbit (Fischinger et al., 2016); social robots like Taizo (Lotfi, Langensiepen and Wada, 2017) and Jibo (Ostrowski et al., 2019). Shishehgar, Kerr and Blake (2019) reported that companion and telepresence robots are the most used robots for older adults, implying positive effects on targeting issues around social isolation, and physical or cognitive functions. However, robotic assistance that supports independent living is under developed.

The development of assistive robotics for an ageing population is driven by two underlying framings of ageing. First, a deficit approach focuses on the decline of cognitive and physical functions. Second, an active ageing approach sees ageing as a natural process of human experience, and emphasises the diversity among the older individuals (Lee and Riek, 2018). The underlying framing influenced what kind of robots ought to be made in the eyes of developers. In the deficit approach, older adults are rarely involved in the development process. They are stereotyped as frail and lonely individuals in seek of robotic solutions. (Frennert and Östlund, 2014). One of SAR's popular uses is providing companionship, especially with pet-like robots like AIBO and Paro (Kanamori et al. 2003).

Active ageing was a policy framework, and "[a] process of optimizing opportunities for health, participation and security in order to enhance the quality of life as people age" (World Health Organization, 2002, p.12). Under the active ageing framework, technology is considered a way to assist with a broader range of needs and possibilities for older adults to achieve physical, social, and mental well being.

2.3.2 Ethical concerns over assistive/social robots for older adults

The ethical questions around social/assistive robots have gained more attention over the years, for example, the risk of reducing human contact, losing control, privacy, and infantilisation (Sharkey and Sharkey, 2012). A major concern of employing social/assistive robots is the use of emotional expressions and behaviours of robots which leads to deception for older adults. Sherry Turkle (2007) observed older adults interacting with Paro, a zoomorphic therapeutic robot, and analysed participants' self-report therapeutic effects from the interaction. Based on her analysis, she warned that the deception and attachment implications of robots are only pushing humans "darwinian buttons", and such implications should be dealt with careful consideration. In another study, Bradwell et al. (2019) observed older adults interacting with animatronic robots similar to Paro and found participants' behaviours indicated attachment towards robots.

Other than the necessity for roboticists to address these ethical concerns, Giaccardia, Kuijerb and Nevenc (2016) criticised the practice of "gerontechnology" that takes away older adults' agency to make decisions. They argue that older adults should hold the power to use technology as a resource, to benefit their individual ageing process. Bradwell et al. (2019) assessed the importance of a user-centred design approach by comparing the preferences of older users and roboticists, which revealed significant differences in design preferences. It is important to gain insights from older adults' perspectives, regarding what is considered care? What is acceptable for caretakers to give away to robots? What is acceptable for older adults?

2.3.3 Problematic categorisation of older adults

Before engaging older adults in the process, it is worthy rethinking the definition and categorisation of older adults in HRI research. Traditionally, chronological age is used to indicate population ageing; 60 or 65 years or over are defined as older adults (United Nations, 2019, p. iii). The heavy emphasis on physical and cognitive decline oversimplifies the heterogeneous nature of individuals' ageing experiences. In more recent studies, the conventional notion of designing for an ageing population that frames older people as a problem to be addressed with robots is challenged. Attitudes towards the diverse functions of robotic devices depend on older adults' health conditions. Literature on older adults' attitudes towards robots designed for eldercare mainly focused on a demographic that suffers from declined physical or cognitive conditions and older adults who live alone or in care homes.

On the other hand, Deutsch et al. (2019) found that cognitively healthy older adults are open to adopting robotic devices if robots can address four users' needs, including “[…] the need for authenticity, the fear of being replaced, the need for independence, and the need for control” (p.129). Righi, Sayago and Blat (2017) investigated the fundamental problem of categorising older adults by going beyond adopting participatory methods, and pointed out that the limitation of addressing specific attributes of older adults fails to recognise older adults’ sociocultural contexts. In other words, older adults are members of social communities that interact with other people in a broader range of activities.

A case in point is China, with an ageing population of 120 million predicted by 2050, where researchers are trying to develop robots that meet the demands of older adults, including a cooking robot for older adults who are wheelchair users (Ma et al., 2011). A limited number of studies have been conducted on the Chinese elderly’s psychological and emotional preferences in robots. One study focused on women who lived alone and suggested that older women desire companion robots that are socially aware, capable of problem-solving and have a personality (Gao et al., 2018). Few early-stage ethnographic works engaged with an active ageing perspective are conducted to develop socially assistive robots in China. Few studies engaged Chinese older adults as co-designers, except for one relevant study by Kwan, Yick and Wong (2019) that engaged older women to co-create footwear in Hong Kong. In China, many more older adults are starting to retire at the age of 55 and remain active and healthy (Wu et al., 2018). It is necessary to engage healthy retired adults in the early-stage development of assistive robotics.

2.3.4 The impact of cultural background

Cultural backgrounds influence users’ perceptions and attitudes towards robots (Haring et al., 2014). In one cross-cultural study of negative attitudes towards robots, Bartneck et al. (2005) compared Chinese participants’ attitudes with those of 6 other countries. The results suggest that attitudes toward interaction and the social influence of robots differ significantly among nationalities, while age influences participants’ attitudes towards emotion when interacting with robots. In another study, Li et al. (2019) compared Chinese adults’ preference of normative behaviours in 15 specific scenarios to those of American participants. They suggested that the Chinese prefer robots that are more compliant with social norms and be considerate of human feelings. It is clear that social robots need to respond with cultural compatibility to their intended users. However, there is still a lack of study on the specific concerns and opportunities in China’s cultural context that influence older adults’ attitudes and expectations for robots designed for ageing. In addition, attitudes towards dogs and familiarity with assistance dogs and dog training in China differ from western countries.

All aspects mentioned above are likely to contribute to the overall attitudes towards socially assistive robots. Design research can inform the understanding of user context in support of the social embeddedness of human-robot interaction (Kaptelinin et al., 2017). Gaining a deeper understanding of the ageing experience of the healthy retired adults could provide more contextual information about their attitudes and preferences towards social/assistive robots and provide insights for developing appropriate social/assistive robots for them.

2.3.5 Preferences for appearance, function and interaction

2.3.5.1 Appearance

Robot appearance plays a critical role in humans' perception and acceptance of a robot. People's expectation about robot appearance is dependent on the application domain (Phillips et al., 2017). The type of robot appearance impacts 'perceived social presence, sociability, and service evaluation of a robot' (Kwak, 2014). A human-oriented appearance is perceived to have a higher social presence and be more suitable for emotion-oriented situations. In contrast, a product-oriented appearance improves service satisfaction; hence it is more suitable in task-oriented situations.

Older adults generally expect small-sized robots that fit into the home environment (Prakash, Kemp and Rogers, 2014), while preference over the material, facial features, bodily features and indications of gender identity diversify among individuals. There is no one-size-fits-all solution towards the robots' appearance, colour, and material. Caleb-Solly et al. (2014) found that human-like and pet-like features are more appealing, while some show no apparent preference over the two.

Zoomorphic and anthropomorphic robots have features like eyes and faces, which differentiate them from object-like robots. However, some object-like robots still have a 'head', like ElliQ. The primary differentiation between zoomorphic and anthropomorphic robots would be their size. For example, zoomorphic robots like AIBO are only about 30cm in length; anthropomorphic robots like Pepper and ASIMO stand about three feet tall. However, there are exceptions like RoboBear, where a zoomorphic face is matched with a human-like body and stands about four feet tall, and NAO robot, a humanoid that is only 58cm tall. Though no consensus is reached on preferred appearances, gender and cultural background are likely to play significant roles in users' preferences of robot appearance.

2.3.5.2 Function space

Driven by a deficit approach (see section 2.3.1), many studies focus on providing older adults assistance to accommodate their declined physical health. However, healthy older adults prefer multifunctional robots that provide preventative interventions and educational content to stay active and independent at home (Robinson, MacDonald and Broadbent, 2014). Home is a private space, a much different habitat for robots to navigate than public spaces, like shopping malls, hospitals, or care homes. Private homes involve more participation of informal caretakers than professional nurses and caretakers. The repetitive tasks that need to be done at home are different to those in a hospital. The functions of great value in a hospital might be obsolete at home.

2.3.5.3 Interaction styles

Robot's interaction style affects users' trust and acceptance of the robot. Interaction styles could be categorised as autonomous, human-led, and robot-led; people prefer the robot-led interaction style in tasks that require higher cognitive load and the human-led interaction style for joint actions (Schulz, Kratzer and Toussaint, 2018). The human-led interaction style is also reported to improve the perception of self-efficacy in human-robot interaction in a study with Pepper, a robot that used verbal expressions to explore interaction styles (Zafari et al., 2019). Interaction style consists of multiple factors, besides whether a robot or human takes the lead in a task. Older adults expressed preference for different levels of interaction concerning frequency, context and whether surveillance is involved (Chu et al., 2019).

Older adults were open to the methods of controlling robots and how robots interact with them. Voice command is the most commonly known and preferred method for older adults to control robots (Beer et al., 2012). While older adults prefer a human-led interaction style, robot-led interactions are welcomed as long as a sense of control is maintained (Deutsch et al., 2019).

In my research, I suggest that the development of a social/assistive robot requires refinement in the following ways:

1. A niche function that is useful for the end-user and can learn new tasks throughout time.
2. The role of the social behaviours is appropriate to the function.

3. The combination of function and social interaction reflects the values of the end-user.

Dogs are the most familiarised non-human species that formed a symbiotic relationship with humans in domestic and other working contexts. Working dogs operate in niche professions and provide humans with emotional support in a mutual relationship. Therefore, human-dog interaction provides a metaphor for social/assistive robots. Also, given the nature of the continuous relationship between humans and dogs, I argue that enabling end-users to develop the specific ways a robotic agent should behave in the user's contexts is an effective way to meet the user's idiosyncratic needs and changes over time. The needs of older adults should be carried beyond the initial development phase. Socially assistive robots should support a co-shaping process in response to the diverse needs of older adults.

2.4 "Research *through* Design" in Human-Robot Interaction

2.4.1 Applicability of dogs as a model for robots

It is unclear to what extent human-dog interaction is a good model for human-robot interaction. In response to Miklósi's suggestion of using dogs as a model for social robots, Feil-Seifer (2014) pointed out the limitations of using human-dog interaction as a model for socially assistive robots. He argued that a robot that behaves like a dog is only appropriate for companion robots that look like dogs. Companion-type robots are developed based on the stereotype of older adults as frail and dependent individuals who need companions. Beyond the category of companion robots, the authoritative role robots might take in healthcare, which does not match the subordinate dog position in human-dog interaction (Dahl, 2014). Faragó addressed the criticism by arguing that the question of dominance and submission is irrelevant, providing human-dog dyads in the working context as an example, where the authoritative positions are exchanged between humans and guide dogs.

On the other hand, emphasising the cooperation and trust formed between dog and owner while performing cooperative tasks helps highlight other features in human-dog interaction that are preferable in the interaction with older adults (Phillips et al., 2016). Service dogs learn specific stimuli and behaviours for effective teamwork in different contexts. Studying social behaviours in human-dog teams could inform the development of socially assistive robots in situations where cooperation is preferable, such as when a guide dog helps its owner to navigate space (Faragó et al., 2014), or when an assistance dog helps its owner by fetching objects and carrying them back to the owner (Miklósi and Gácsi, 2012).

A number of ethological studies of canine behaviour suggested that social behaviours can be applied in robots of various forms, which is advantageous in developing robots whose forms need to follow the niche functions they serve. However, the robot forms used in these studies are not far from the usual forms of lab robots, a head with simple facial features that sit on a cylindrical body and navigate wheels. In previous studies, the robots only fulfil a singular function in a particular scenario, and the effectiveness of such social behaviour in various forms and across different contexts remains unclear. The studies illustrate the applicability of dog's interactive behaviours rather than defining a niche function of the robot. The niche functions of robots remain unclear; while Dautenhahn (2004) suggested the need to be defined based on extensive user studies; Auger (2012, pp.184–189) took a speculative design approach and showcased three carnivorous robots that serve familiar functions at home.

To understand the relevance of the three approaches of Auger, Dautenhahn and Miklósi and others mentioned in section 2.1. I borrow from Dorst's idea of abduction as the core of design thinking, specifically his categorisation of two types of abduction. Dorst states:

> In abduction-1 (closed problem solving), one develops an object ("what"), based on a given desired outcome ("result") and a given working principle ("how"); in abduction-2 (open problem solving), one starts with a desired outcome ("result") and develops both an object ("what") and a working principle ("how"). (Steen, 2013)

All three interpretations of the robot-as-dog metaphor show the usefulness of seeing future robots as domestic dogs today. Dautenhahn's and Miklósi's approaches to dogs as a model for future robots can be understood as abduction-1, which aims to develop a particular robot based on a given niche function to fulfil and known engineering plans. On the other hand, Auger's conclusion can be understood as abduction-2, whereby he expressed a desire to create a domestic robot, and questions the possible adaptations of robot forms, functions and interactions with humans.

2.4.2 Metaphor and its implications in "Research *through* Design "

Schön (1979, p.139) argues the crucial role of metaphor in problem-setting; instead of focusing on problem-solving, he calls the making of generative metaphor to generate new perceptions, explanations, and inventions. In the three framings of the robot-as-dog metaphor, it is evident that the metaphor led to different proposals for developing robots in domestic environments.

Illustrated by Schön's use of generative metaphors in domains of social policy and technological research shows that generative metaphor can be useful as an interpretative tool for critical analysis. In the previous section, the three framings of the robots-as-dogs metaphor are based on different examinations of analogies and disanalogies, and the extent to which they are applicable. The key difference among these framings is the level of abstraction. Schön points out that the metaphor is dependent on the depth of understanding of the source domain, in this case, human-dog interaction, the selected analogies and disregarded disanalogies in each framing proposed by Auger, Dautenhahn, and Miklósi are reviewed (in section 2.2).

It is important to understand the difference between analogy and metaphor. Both analogy and metaphor involve mapping a source domain to a target domain. The source domain refers to the conceptual domain from which metaphorical expressions are drawn, and the target domain is the domain to be understood (Lakoff, 1933). For example, in the robot-as-dog metaphor, the dog is the source domain, and the robot is the target domain. According to Gentner and Markman (1997), metaphor covers the span of appearance similarity and relational similarity, while analogy maps relational and structural similarity (figure 2-8). Each has its own advantage; analogy provides new perspectives to interpret a problem. Metaphor focuses on transferring knowledge from a known source domain, to understand an unknown domain (Choi and Kim, 2017, p.31).

Figure redacted for copyright regulations, please find the diagram from: Choi, H.H. and Kim, M.J. (2017) 'The effects of analogical and metaphorical reasoning on design thinking', Thinking Skills and Creativity, 23, pp. 29–41. doi:10.1016/j.tsc.2016.11.004.

Figure 2-8 Relationship between analogy and metaphor modified from Gentner and Markman (1997) by Choi and Kim (2017, p.31).

Metaphors are used throughout the stages of the design process, namely design concepts ideation, framing design situation, defining goals and constraints, and mapping and applying structural relationships in the source domain to problems found in the target domain (Casakin, 2006). In this thesis, the source domain is found in the relevant aspects of human-dog interaction, and the target domain is human-robot interaction. The amount of experience or knowledge of the source domain could increase the understanding of the target domain.

To further understand the relevance of three framings in relation to RtD methods within HRI, it is useful to review the model of "research *through* design" within HCI (figure 2-9) proposed by Zimmerman and Forlizzi (2014, p.177). The model positions experts from three disciplines — engineering, anthropology and behavioural science in separate categories which reflect the type of knowledge each group is engaged with, and places interaction designers as a catalyst point where artifacts are produced for research. In this model, interaction design researchers try to tackle wicked problems found in HCI, and seek to 'integrate the true knowledge (the models and theories from the behavioural scientist) with the how knowledge (the technical opportunities demonstrated by engineers)'.

Figure redacted for copyright regulations, please find the diagram at: Zimmerman, J. and Forlizzi, J. (2014) 'Research Through Design in HCI', in Olson, J. S. and Kellogg, W. A. (eds) Ways of Knowing in HCI. New York, NY, USA: Springer, pp. 167–189.

Figure 2-9 Model of "research *through* design" within HCI proposed by Zimmerman and Forlizzi (2014, p.177).

This model reveals the different problem framings from each discipline, and how interaction design researchers need to balance the intersecting perspectives, which provides a practical framework for understanding the role of design research in human-robot interaction.

2.4.3 The use of co-design methods in HRI research

Co-design originates from the Scandinavian participatory design in the 1970s. The participatory design approach engages users and stakeholders on different levels during the design process. Co-design and participatory design are often used interchangeably. However, co-design emphasises supporting users to engage in joint inquiry as co-designers. While participatory design methods have been established in HCI as a 'third space' (Muller et al., 2012), a limited number of studies involved users as co-designers in HRI. In one study, Björling and Rose (2019) engaged teenagers in co-designing a social robot to improve their mental health. In another study, Leong and Johnston (2016) learnt that pet dogs provided companionship, a sense of security, an opportunity to socialise, and comfort to older adult participants. Based on these findings, they conducted three group workshops co-designing a robotic dog that can locate their phones, increase social interactions, and provide companionship at home. Then, two more workshops with new older adults evaluated the robotic dog from previous workshops. Other studies also applied multiple methods to engage with older adults; for example, Šabanović *et al.* (2015) utilised semi-structured interviews, home visits, and two workshops to materialise participants' visions by sketching. Iacono and Marti (2014) used storyboard, gameplay, and interactive simulated scenario to develop a graphical user interface for controlling future robotic systems.

Ostrowski, Breazeal and Park (2021) reported this lack of adoption of co-design methods in HRI, due to a lack of robotic platforms and guidelines or methodologies to engage users as co-designers. In this research, healthy retired adults and roboticists are engaged as co-designers to further explore the role of "research *through* design" in human-robot interaction, focusing on the intersecting perspectives provided by all participants, and investigating the relevant aspects of the robot-as-dog metaphor in human-robot interaction.

3 Methodology

This chapter starts by discussing some of the rationales and assumptions in methodologies in human-robot interaction. Then, I will explain the methodological challenges and tensions found when "Research *through* Design" is applied within the field of HRI. In this research, as mentioned earlier, I follow a pragmatist approach. Thus, I will explain how my practice progressed based on a pragmatist perspective, reflecting my epistemological and methodological commitment. The following sections focus on metaphor, ethics, and co-design in relation to pragmatism and how they drive the methods I used in each study are detailed in each subsequent chapter (Chapters 4–7).

3.1 "Research *through* Design" in HRI

"Research *through* design" (RtD) is at an early stage of establishing itself as a paradigm in the field of human-robot interaction. The conventional approach in HRI focuses on creating and evaluating a particular robot function. Instead, RtD seeks to answer the question of what the right robot is to make (Luria, Zimmerman and Forlizzi, 2019). The underlying epistemology and methodology drive the emphasis on RtD and HRI. This different emphasis is exemplified by the observations in the analysis of the ways cultural probe is adopted in the field of HCI, as Boehner et al. (2007) argued that there is a "desire to turn reflective, interpretive research methodologies into formal, packages, and ideally objective methods"; a similar desire could be observed in the current field of HRI. The goal is not about finding a unified methodological approach, but about understanding the wide range of practices in HRI, and avoid methodological battles (Dautenhahn, 2007). This research hopes to further acknowledge the RtD paradigm in relation to other practices grounded in qualitative, quantitative, or experimental paradigms.

The prevalent research paradigm in human-robot interaction could be described as adhering to the "science of design", whereas the "research *through* design" paradigm commits to "an epistemology of practice" (Cross, 2001). John Dewey's pragmatist philosophy provides scaffolds and concepts that are key to design thinking and of value on both a theoretical and practical level (Dalsgaard, 2014). In the following three sections, I will explain how pragmatism influenced my methodology.

3.2 Pragmatism and Metaphor

In my research, I borrow Donald Schön's explanation of 'metaphor' which refers to both a product and a process (1993, p.137). Metaphor as a product provides a unified framework to understand Auger and Dautenhan's use of the domestication of dogs as a model for robots. Both Auger and Dautenhahn propose that future robots could be seen as domesticated dogs. Dautenhahn provides a framework, and Auger presents a methodology to speculate on the possibility of domestic robots. As "a process by which new perspectives on the world come into existence" (ibid), metaphor is evidenced in Auger's and Dautenhahn's conclusions, providing new perspectives on how future robots could come into existence.

Based on Coyne and Snodgrass's idea that "models of the design process may in fact be viewed as relatively useful or useless metaphors" (Melles, 2008), Dautenhahn's model and Auger's comparative analysis of the domestication process as examples of useful metaphors. It is worth noting that metaphors are used to define problems and suggest how to solve them, and "opportunities for useful actions" are caught when a metaphor is treated with criticism (Snodgrass and Coyne, 1992, cited in Melles, 2008). The role of metaphor in problem framing and solution is shown in both Dautenhahn's model and Auger's analysis of domestication. Auger and Dautenhahn highlight the transition from laboratory to domestic, a two-phase process. Dautenhahn uses the socialisation of dogs as a metaphor, to describe the formulation of a robot's fixed settings in laboratory. This echoes Auger's idea of how technology becomes a product. Following a hypothetical robot in Dautenhan's model, or the robotic product in Auger's argument, the robot then goes through a phase where it adapts itself to a person's preferences. Dautenhahn describes it as personalisation in the home environment. Similarly, Auger explains dogs adapt to domestic life by achieving a post-utility function.

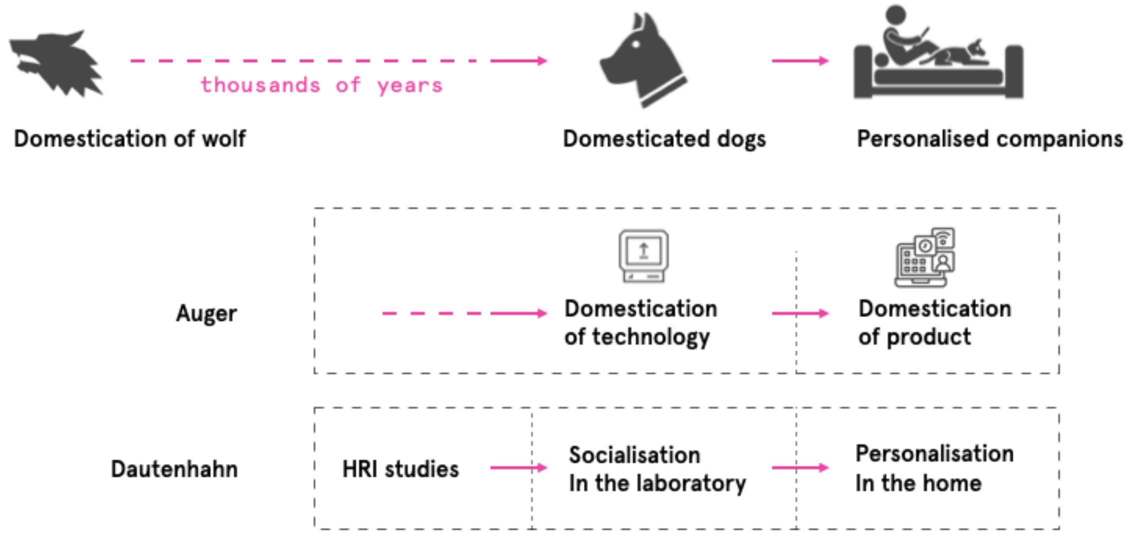


Figure 3-1 Metaphors found in works by Auger and Dautenhahn, in comparison to the domestication process of dogs.

Auger explored whether a robot could become a domestic product, and how it might become through speculative design practice. In Auger's comparison of dogs to products and interpretation of robots as domestic products, the metaphor is operated within a relatively short time frame, unlike the process of the domestication of dogs from the wolf, which has an evolutionary history of thousands of years. Therefore, Auger pointed out the tension between the advantages of robotic technology and the warmth of home; a series of carnivorous robots are presented to showcase the necessary form, functional, and interactive adaptations, which derived away from being analogous to domestic dogs. On the other hand, Dautenhahn (2004) follows a developmental model of socialisation which accounts for the critical period of social development in a puppy's early life.

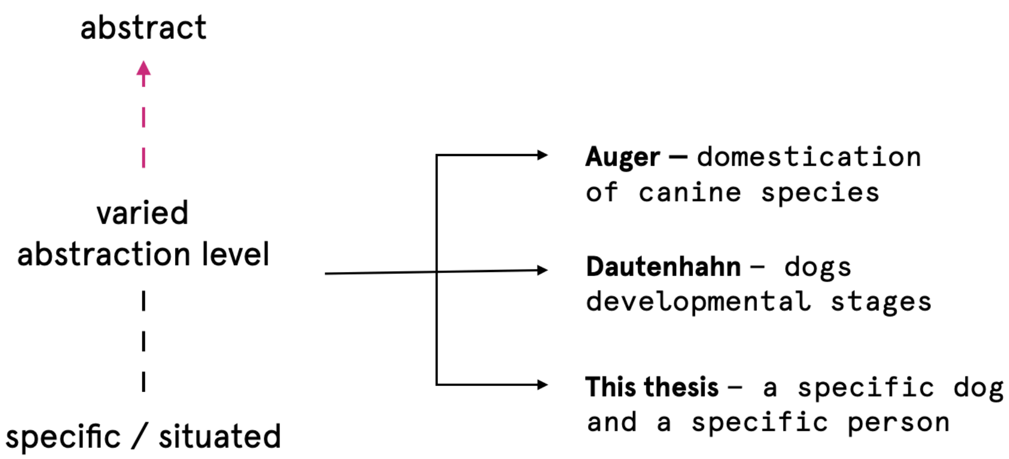


Figure 3-2 The varied levels of abstraction applied to the source domain in Auger's and Dautenhahn's work, and where this thesis is positioned in relation to their work.

In this thesis, I also treat human-dog interaction as a metaphor. However, unlike Auger and Dautenhahn who draw insights from evolutionary studies of the canine species, and the developmental stages of dogs, respectively. I observe and analyse interactions between a particular person and a particular dog, instead of dogs as a species in general (figure 3-2). In other words, if Dautenhahn's and Auger's framings were determined by their choice of at which level they study the source domain, it is safe to assume that studying human-dog interaction at a situated level would bring new perspectives.

3.3 Pragmatism and Ethics

There are three ethical considerations taken into account in this research. Firstly, this research deals with an underlying ethical concern that questions the motivation to develop robots for older adults in the first place. Many more researchers explore how robots are not to replace humans, especially caretakers, in the context of eldercare (Tuisku *et al.,* 2019; Hosseini and Goher, 2016). Following Dewey's pragmatist philosophy that knowledge is "particular" and "contingent" (Dewey, 1920), this research explores the possible roles and tasks a robot could take on within specific scenarios.

Secondly, this research uses the human and dog interaction as a model to speculate on the possibility of human and robot interaction, which brings the question of 'what humans and what dogs' proposed by Haraway (2008) in her analysis of her training experience with her dog Cayenne. She explains the experience is "a historically located, multispecies, subject-shaping encounter in a contact zone fraught with power, knowledge and technique, moral questions—and the chance for a joint, cross-species invention that simultaneously works and play" (p. 205). The choice of the human-dog dyads observed in this research directly calls for ethical consideration. This requires a reasonable understanding of dog training techniques derived from two schools of animal behaviour, ethology, and behaviourism. In this research, working dogs are trained with trainers who follow positive reinforcement training techniques. Positive reinforcement training means the trainer rewards the desired dog behaviours and ignores the undesired behaviours instead of punishing the unwanted behaviours (Hiby, Rooney and Bradshaw, 2004).

Lastly, Dewey's pragmatism aims to involve diverse people in a cooperative process to improve the current situation (Hildebrand, 2021). In this research, I recruited both roboticists and retired adult participants to jointly explore questions around social and assistive robots through a co-design process. Further discussion is found in Chapter 6.

3.4 Pragmatism and Co-Design

Steen discussed the ethos of co-design following Dewey's pragmatist philosophy. Pragmatist ethics does not focus on general rules found in two dominant schools of ethics (consequentialist ethics and deontological ethics), but rather on the 'ordinary life-experience of inherently social, embodied, and historically situated beings' (as cited in Steen, 2008). In this research, I explored how human-dog interaction can provide a lens to investigate human-robot interaction through two co-design projects. I refer to Dorst's understanding that abduction is the core of design thinking and his explanation of two types of abduction (see section 2.3.2). Steen draws on the ideas of Dewey's pragmatism, and explains that the co-design process is collaborative design thinking that involves diverse participants (ibid).

Sanders and Stappers (2014) outlined three approaches to the role of making in co-design activity, which corresponds to different mindsets, focus on time, and intentions. They summarised the approaches as probes, toolkits, and prototypes. In this research, a Wizard-of-Oz prototype as a probe is used in study 3 (chapter 6). Chapter 6 describes a co-design process with two roboticists and a retired participant to carry out a joint inquiry. The study reflects how two types of abduction in a collaborative team could steer the direction of the problem setting in an explorative study of a possible robot for the retired participant. Chapter 7 describes a co-design project with eight retired participants within an iterative process which includes discussion, drawing together, and storyboard to understand how the contingent conditions shape ideas around robots in relation to form, function, and interaction.

3.5 Methods Overview

The preceding sections explain the methodological commitments of this research, which inform the methods I apply in each of the studies. The table below (Table 1) shows the methods aligned in each project. Specific details about participants (human and dog) and the methods used within each study are contained in their respective chapters.

In each of the studies, I had ethics clearance for the research through the Royal College of Art's Ethics Committee. Abiding by the RCA's ethics guidelines, all human participants were presented with a research information sheet for at least two days to consider their involvement in this research. Dogs were observed under the supervision of their owners or during their regular training sessions with handlers. Human participants signed consent forms to affirm their willingness to participate. Participants were acknowledged that they could leave the study at any time. I ensured adhering to ethics processes with the participants in each of the studies.

Project / Chapter	RQ	Methods	Data Collection	Analysis
1 / chapter 4	1	- Participatory observation - generative metaphor	- video recording - field notes	Interpretative analysis
2 / chapter 5	2	- Semi-structured interview	- audio recordings	Thematic Analysis
3 / chapter 6	1	- Co-design - WizardOz - Probe	- field notes - video recordings	Reflective-in-action
4 / chapter 7	2	- Co-design - Storyboard	- drawings - audio recordings	Thematic analysis

Table 1 Methods overview.

The research began with exploring human-dog interaction by observing a pet dog, a guide dog, and a police dog interacting with their owner, trainer, and handler. Three aspects of human-dog interaction (detailed in section 4.6) were potentially useful for human-robot interaction in Study 1. Following the findings of Study 1, Study 2 explores recently retired older adults' attitudes towards robots for eldercare in general and their needs regarding service robots in China. Comparing the findings from these two studies, provides answers to the first research question: 'in what way human-dog interaction could inform the design of social robots that meet the needs of older adults.

To further explore the roles of aesthetic, functional and interactive aspects of the human-dog interaction that play in older adults' interaction with social robots, study 3 and 4 are conducted. Study 3 explores a co-design process that contributes to HRI research when the researcher works with roboticists. In most human-robot interaction studies, design is positioned prior to building a robot to inform the final design of the robot. These studies are mostly concerned with determining a specific set of functions through user studies. In HCI, it is established that design can contribute to all phases of developing a product or service. Study 4 is carried out in three sessions. Retired participants are invited to discuss three comparisons which focus on the interplay between (1) form and function, (2) function and interaction, and (3) form and interaction in each session. Along with the discussions, the participants are invited to sketch with the researcher to create a robot that could be useful. Sketching enables an iterative co-design process for participants to change ideas in response to the discussions without overthinking technical issues and concentrate on scenarios. After each session, a sketch is generated, and used to facilitate the discussion in the next session.

3.6 Methodological Limitation

This research took on a flexible design strategy, considering the large population of older adults in China. This research does not aim to represent the heterogeneous population with vast differences regarding their levels of education, financial and social status, nor aims to achieve the statistical generalization usually found in fixed research design strategy (Robson and McCartan, 2016). A sample size of sixteen retired adult participants was selected to reveal insights of a group of older adults who are cognitively and physically healthy, financially stable, and familiar with the community-based retirement life. The participants include eight male and eight female participants that recently retired from their jobs at a university in Nanjing, China. This limited sample size allowed me to undertake semi-structured interviews with the participants, which provided contextual information about their individual lives. Twelve participants were initially recruited through the eight out of the sixteen participants are dog owners, and purposely recruited four dog owner participants through the snowballing method. A smaller sample also allowed me to carry out co-design workshops online during the Covid-19 pandemic after building a rapport with the participants during the previous study.

Participants were recruited from similar economic backgrounds and shared a connection to the Activity Centre at Nanjing University of Science and Technology. China's pension system has undergone a significant change in recent years (Zhu and Walker, 2018). Activity centres are often built for retired adults under the influence of the employer-based pension system. Compared to the participants recruited in this research, a large number of older adults over 55 years old do not share the same privilege of having a community centre. The participants recruited are likely to be early adopters of robotic products. The findings are influenced by older adults' shared experience of having a community, and the opportunities found in Study 2 (section 5.3) can not represent a broader demographic of older adults in China. However, it might provide some ideas of how robots could fit into a community-based network of eldercare services.

In this study, the retired adult participants do not have experience with dog training and have little interest in training their pet dogs, except for one with extensive experience. There is no formal study on whether dog owners in China are more aware of the benefits and importance of learning about dog behaviours and training techniques. A recent study examining the political history of the human-dog relationship in Beijing suggests a rise in understanding of human-dog interactions (Jeffreys 2020). However, the awareness and practice of professional dog training are still very limited in China at the moment. It is difficult to draw conclusions about the differences between dog owners and non-dog owners.

Practice Part 1

In the first part of practice, the overall goal is to gain insights into the source domain and target domain by conducting two explorative studies to explore the human-dog interactions and older adults' attitudes and preferences toward social/assistive robots. Starting with study 1, the source domain, I focused on observing specific human-dog dyads in different contexts to further understand the source domain and human-dog interaction. Then, study 2 to understand the target domain of developing social robots for older adults. Both studies generated findings that could be useful for human-robot interaction. For example, findings in Study 2 about healthy retired adults' attitudes and preferences towards social/assistive robots suggested key routes to improve the acceptance of robots among older adults, namely the possible integration with a health service provider or a community-based renting service. However, in this thesis, to answer the research questions, only relevant aspects of human-dog interaction from Study 1 that intersect with Study 2 inform the later studies presented in Part 2.

Here I restate research question 1, how could and in what way the human-dog interaction model informs the design of social robots to meet the needs of older adults?

4 Study 1: Exploration of human-dog interactions

4.1 Overview

This is an explorative study with the aim of understanding the characteristics of interaction between humans and dogs in three different types of work, namely pet dogs, police dogs, and guide dogs. First, I want to find out the similarities and differences in the interactions with the pet, guide, and police dogs. Second, I want to understand the interaction characteristics of each type of human-dog dyad. Third, for each dyad, I want to understand the way each modality of communication is used between humans and dogs. Lastly, I will summarise the relevance and potential application of the findings to the field of Human-Robot Interaction.

More specifically, I observed how the vocal interactions, non-verbal gestures and frequency of turn-taking are orchestrated differently in the three types of human-dog interactions. The findings suggest that different tasks involve different interaction dynamics between the dog and the human, and that each dynamic requires humans and dogs to adopt particular patterns of communication. These patterns could provide insights into the aspects of human-robot interaction. It is understood that both police and guide dogs take on companion roles when they are off duty. Therefore, the focus is not on a single role or function the dog possesses, nor the affections or relationships humans build with dogs; instead, the emphasis is on the interaction characteristics and the key mechanisms behind each type of human-dog dyad.

4.2 Methods and Procedure

In order to observe and compare three different types of dogs, my first port of call was to contact the Nanjing Police-Dog Research Institute, China Guide Dog Training Centre in Dalian, and a professional trainer in Chengdu to gain an understanding of interactions between humans and police, guide and pet dogs.

The dog trainers were recruited in two ways. In the case of dog trainers of working dogs, I contacted Nanjing Police-dog Research Institute and China Guide Dog Training Centre through phone numbers provided on their official website. I briefly introduced myself, and explained my research interest. Then, I asked for permission for a quick visit at each facility. The institutes recognised my sponsorship and granted me access.

To recruit a professional dog trainer, I reached out to my friend who works in the fresh dog food industry. I explained my intention to observe and interview professional dog trainers who work with both pet dogs and their owners. A short description of the project, and participant inclusion criteria were sent to my friend's contacts. A professional dog trainer, Ruby, contacted me via text message.

4.2.1 Guide dog-human interaction

China Guide Dog Training Centre is in Dalian city. Founder of the China Guide Dog Training Centre, Dr Wang, explained each stage of guide dogs training while giving a tour of the training centre. Afterwards, I conducted a one-hour interview with Dr Wang to learn in-depth information about guide dogs. In the end, a Golden Retriever guide dog, Doudou, led me to walk past a number of obstacles under the supervision of her trainer, Lin. Doudou, a 3-year-old Labrador Retriever, graduated from the training program and stayed at the centre for the co-training program with her human handler. Doudou is a playful dog when she is off duty.

It takes 2.5 to 3 years for a guide dog to start working with visually impaired owners at China Guide Dog Training Centre. Golden Retriever and Labrador Retriever are selected to breed at the centre because of their excellent temperament, intelligence, stability, and medium size. A foster family will adopt a puppy to socialise with humans after 60 days it is born, following the guidelines of the training centre, exposing puppies to new environments and objects, and teaching them simple commands. Once the puppy reaches 12–14 months of age, it will be sent to the training centre for an 18-month long training. After it is qualified, it will be paired with a visually impaired owner to train together for 4–6 weeks.

4.2.2 Police dog-human interaction

In a one-hour interview, animal behavioural scientist Dr Wu introduced the types of police dogs at Nanjing Police-dog Research Institute, including search and rescue, detection, and patrol dogs. Dr Wu explained the interaction between a handler and a police dog while handler Liu demonstrated a series of commands that human-led the interaction, and Lele followed the orders. Lele was a 2-year-old German Shepherd. He and his handler, Liu, recently graduated from the training program.

The institute trains medium-size dogs for a range of police work, for example, patrol, track, search and rescue, detection, and attack. German Shepherd, Labrador Retriever, and English Springer Spaniel puppies are bred and selected through a process where agility, obedience, cognition, courage, aggression, hunting drive, environmental stability, and many more factors are evaluated before a dog can start the training. It usually takes about 18 to 24 months to train a police dog at the institute.

4.2.3 Pet dog-human interaction

Ruby is a professional dog who was working in China. She mainly worked with pet dog owners and other dog trainers. When the study was conducted, Ruby led training sessions with dog owners and their dogs in the city of Chengdu. She taught pet owners training techniques that they can continue to use with their dogs throughout time. I observed Ruby training Sarah and her dog Dobby. Dobby was a 1-year-old Jack Russel Terrier with a lot of energy. Sarah, the owner, worked in the city as a young professional and lives alone with Dobby.

Ruby, gave descriptions of pet dog training and enrichment games for pet dogs in a half-hour interview. Then, Ruby introduced me to Sarah and Dobby at their home, where I observed one training session. Another training session took place outside where Sarah was living, where I also observed Ruby teaching Sarah how to train

Dobby. After each observation, semi-structured interviews were conducted with the dogs' handlers (Ruby and Sarah) to elicit opinions about dogs, training, and socially assistive robots.

Another pet dog owner (P14d) provided videos of her playing with her dog, Ami, a 5-year-old Toy Poodle. Participant #14 shared her insights into the role of playing in her interaction with Ami in a 30 mins interview.

4.3 Data Collection and Analysis

I observed the interactions between humans and dogs under three categories, pet dogs, guide dogs, and police dogs, captured through first-hand video recordings and video materials provided by professional dog trainers recruited for this study. First-hand video recordings provide preliminary observations to identify characteristics of each human-dog dyads, using an ad libtium sampling strategy, whereby 'no systematic constraints are placed on what is recorded or when' (Martin et al., 1993, p.84), but capture all interactions between the dog and the human partner.

For analysis, a preliminary coding of all clips was carried out to identify the unit of analysis by limiting to one specific goal. Then, an ethogram was created based on the previous work on dog behaviours (Abrantes, 1997; Aloff, 2005). This was complemented by multimodal interaction analysis, which integrates the verbal and the nonverbal communication signals exchanged within human-dog interactions (Norris, 2004). Vocalisations by human partners in each interaction were transcribed.

4.4 Findings

4.4.1 The mediating role of harness in guide dog-human interaction

In this study, Doudou, the guide dog, led her handler pass through a narrow doorway with an obstacle (a planter) upon entrance to sit down. Doudou stopped at the door to notify the handler and led the handler through the narrow entrance after feeling the movement via her harness. She stopped beside the chair, and pointed her nose towards the chair, to guide the human handler. Then, the handler located the edge of the chair by following the direction of Doudou's nose. The human guide-dog dyad provided a good example where certain physical constraints, in this case, vision, result in an interaction with guide dogs that rely on the movements and mediation of harness to work together. More importantly, a guide dog wears a harness with a handle that their human holds onto when they walk together. It mediates the communication between two partners (figure 4-1). The human senses the guide dog's movement, to know which direction and move their body accordingly. The harness is essential to their cooperation.


Figure 4–1 The harness mediates the communication and cooperation between the guide dog and her human partner.

4.4.2 Play interaction in pet dog-human interaction

Both humans and dogs can initiate play and decline by either partner. Sometimes, the play doesn't happen. The following images show that the owner wanted to play tug with her dog Dobby, but Dobby did not want to give away the new toy. The owner lured Dobby with a treat, grabbed the toy from Dobby, then dangled the toy above Dobby's head and gained attention from Dobby by calling her name (figure 4-2).


Figure 4-2 Dobby sits still while staring at the toy.

Dobby was distracted, and the owner did a little dance move to get Dobby's attention. Dobby quickly reached for the toy without tugging. The owner retracted the toy, called “Dobby” again, patted her thigh, and called “come over” to get Dobby to play on the floor. Dobby did move down from the sofa but did not engage in tugging with her owner.

Dobby occasionally gazed towards the owner; however, the owner was busy (figure 4-3).

Figure 4-3 Dobby is playing with a ball.

4.4.3 Police dogs completing tasks on command

In my observation, the interaction between the handler and the dog was precise and effective. Verbal commands were reduced to one syllable vocalisation, followed by a sequence of standardised actions carried out by police dogs and handlers. The police dog remained in consistent proximity to its handler when travelling together and always travelled on the handler's left side. As soon as the handler turned around, Lele followed the handler and adjusted his position to be on the handler's left side (figure 4-4).

Figure 4-4 Police dog Lele travels on the human's side with consistent proximity.

In my observations, both verbal cues and tactile signals were used to communicate with the dog. The handler vocalised 'hao' (literally meaning 'good') immediately after the dog completed a sequence of actions to mark the desired behaviour. A quick tactile signal which involved a quick brush on the head of the dog or the lower back of the dog, was also used by the handler as a secondary positive reinforcement for the dog. Secondary reinforcers were preconditioned by the trainer (figure 4-5).

Figure 4-5 Police dog handler brush on the dog very quickly.

The dog was able to synchronise with the speed at which the handler was walking or running. The human foot and the dog's front paw were both lifted off the ground; the dog was turning with the human to stay on the handler's left side (figure 4-6).


Figure 4-6 Behaviour synchronised between the handler and the dog.

The police dog followed the handler's instructions accurately. In a fetch task, there was a visible order to the actions of the handler and the dog. The dog acted after the human gave out verbal and hand signals (figure 4-7). However agile and quick to respond, the dog did not act until a command was issued (figure 4-8). The handler was in an authoritative position, verbalised commands with an affirmative tone, and was in control of the dog (figure 4-9).


Figure 4-7 Fetch action, step 1, with verbal cue 'jian' (fetch).

Figure 4-8 Fetch action, step 2, ask the dog to return, 'lai' (come).

Figure 4-9 Fetch action, step 3, 'zuo' (sit), then the dog releases the ball.

4.4.4 Exchanges of control in guide dog cooperation

Guide dogs help their owners to travel independently. The teamwork requires cooperative turn-taking between guide dogs and guide dog owners to travel together safely. A guide dog stops when encountering an obstacle to notify the owner or lead the owner to avoid the obstacle when possible. Guide dog owners decide where to go and give the name of the destination to the guide dog. The guide dogs monitor the cars and other humans in the environment to assist their owners when crossing the streets (figure 4-10) and override owners' commands (figure 4-11) when necessary to guide owners safely to the destination.

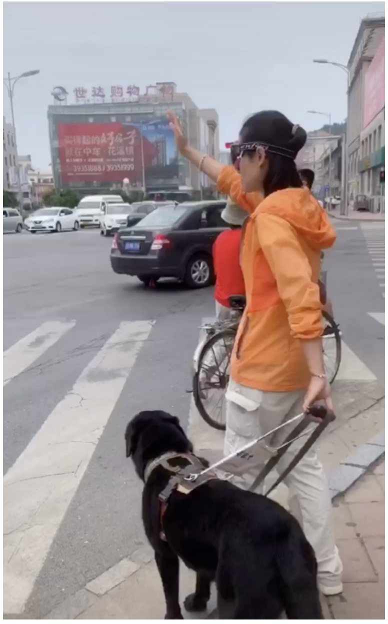


Figure 4-10 Guide dog trainer raises her hand, intending to cross. The guide dog stays still because cars are not stopped yet.

Figure 4-11 Guide dog trainer travelling on the crosswalk.

Figure 4-12 Guide dog stops, and the guide dog owner scopes the area.

Both guide dogs and guide dog owners took on the leading roles and were able to hand over control to the other partner. Cooperation is necessary for both guide dogs and police dogs. The difference is the amount of control that is given to the dog. In the case of police dogs, the human handler takes on more leading roles in the interaction, where the dog's actions follow the handler's commands; however, in the case of guide dogs, the guide dog takes the leading role to guarantee the safety of their owner.

> The guide dogs see their owners as their supervisees, they think they must be responsible to them and are humans' guardians. (Dr Wang, China Guide Dog Training Centre, 9 May 2018)"

For example, the guide dog stopped when encountering a narrow path. The owner stopped to scoop the area with their hand to determine why the dog might have stopped but found no obstacle (figure 4-12); however, the dog remained still. Notified by the guide dog's behaviour, the guide dog owner told the guide dog "to find a new way", and handed over control to the guide dog to lead her. The guide dog turned and chose a passage with more space for the owner to pass safely.

While both guide dog and police dog work in a team and show the ability to synchronise with the actions of human partners, police dogs show a subdominant position when interacting with human handlers, where the dog is trained to obey commands from humans.

4.4.5 Personalisation through training together

Dr Wang explained that the China Guide Dog Training Centre considers the human applicants' needs, personality, and body type and pairs humans and guide dogs with similar personalities. A more active owner will be paired with a dog who has a higher energy level. A larger dog will be chosen to help the owner balance after learning additional skills for owners who might need mobility assistance. The welfare of the dogs is a key concern for the training centre, where guide dog owners must learn and provide care for the guide dog.

After the initial pairing of the owner and the guide dog, both are required to train together in the environment of the guide dog owner’s home environment and places they often travel to. A guide dog trainer will guide the process, and the team must pass an exam of working together for the guide dog to be considered successfully paired.

Pet dog owners train dogs for different reasons, and this often includes the need to correct problematic behaviours or teach their pet dogs to behave appropriately in specific situations. In individual dog-owner dyads, well-behaved dogs can satisfy the needs of both the owner and dog. The training process is highly individualised, and motivated for personal reasons, and the training process carries meanings for individual dyads.

Ruby explained that many behaviour problems in dogs are caused by human owners. Owners repeatedly endorse undesirable behaviour in their dogs, resulting in dogs' misbehaving. Sarah has had Dobby for a while. However, she still had difficulty taking Dobby for a walk and getting Dobby to follow her. Therefore, the task was to get Dobby to behave on walks, and go to Sarah when she calls 'Dobby, come!'

Owners are usually advised to cue their dogs with short verbal words, hand gestures or body movements, and reward their dogs for desirable behaviour with a treat, praise, a pat, a hand clap, or a combination of all. Therefore, a conscious response to dog behaviour helps to reinforce the desired behaviours. For example, Sarah started to call Dobby’s name, and rewarded Dobby with a treat if Dobby looked back at her, then she moved one step backwards, and called Dobby again, followed by another treat if Dobby followed. To avoid confusing signals, Sarah followed a rather strict script to progress one step at a time, and rewarded Dobby with treats.

The training between owners and the dog fosters mutual learning. The owner might learn if her dog is food-oriented or toy-oriented. More importantly, through interacting with and training the dog, the owner reflects on her own behaviour, interaction with her dog, habits, etc. In this study, Dobby was more toy-oriented than food-oriented, and Sarah learnt about her need to have a quiet 20 minutes in the morning, so she wanted Dobby to behave while she was getting ready to go to work in the morning. She then decided to train Dobby to play with toys by herself.

4.5 Discussions

4.5.1 The aesthetic experience in human-dog play

Play interaction is found in both working dogs and pet dogs. Dogs playing with humans is hypothesised as an adaptive trait developed during domestication. Play is a regular interaction between them and their pet dogs for pet owners. Horowitz and Hecht (2016) started to capture the forms of play between pet dogs and their owners, and the vocalisations within the play to investigate the relationship of affect to elements of play. While working dogs are expected to play just like a pet dog when off-duty, some of the behavioural characteristics carry over into their play. In a comparison between police dogs and border guard dogs, police dogs' behaviours in play with handlers show more association with control (Horváth, Dóka and Miklósi 2008). The joyful play has been an aesthetic experience that roboticists try to replicate in robotic dogs; for example, Sony's AIBO claims to provide joyful play with humans. However, due to the limited ability to show complex behavioural of robotic dogs, users prefer the real dog (Kerepsi et al., 2006).

While the specific behaviours of dog play have limited application to social/assistive robots. The omnipresence of play across different types suggests an aesthetic aspect of interaction which could

4.5.2 Multimodal and mediated nature of human-dog interaction

Human-dog interaction relies on both nonverbal and verbal communication; however, an often mismatch is found between human and dog use of nonverbal communication (McGreevy et al., 2012). Facial expressions, body movements, vocal signals, gaze, and gestures are all involved in the interaction between humans and dogs, and coordinate differently in modes of interaction depending on the types of work the dog carries out. Dogs are skilled at reading social signals given by humans; however, humans show varied abilities to interact with dogs, depending on their nonverbal sensitivity and experience (Meyer and Forkman, 2014). The complexity of behavioural patterns also functions differently in play-mode and work-mode. Humans' play signals are not always effective in communicating with dogs, and human partners do not necessarily understand dogs' volition to play. The mismatch of modalities in the communication of the human-guide dog team provides a good example of a mismatch of communicative modalities for human-robot interaction, and a robot needs to match the preferred modality of communication with its user.

Working dogs, namely police dogs and guide dogs, are highly trained to work with humans to accomplish tasks. They learnt how to operate technological apparatus. Human handlers and their guide dogs or police dogs are both trained to understand a set of communicative signals and commands. In the case of a guide dog, the communication relies on the harness. It mediates an embodied communication between the two partners. The handle on the harness allows owners to feel their guide dogs' subtle movements and enhance the feedback exchanges. Guide dogs are encouraged to wear the harness of their own volition, which shows their willingness to work. The guide dogs know that wearing a harness means they are at work. The harness also sets them apart from pet dogs in public and notifies people not to disturb the guide dog.

4.5.3 Exchanges of control in human-dog cooperative interaction

Police dogs are trained to assist law enforcement officers in a number of activities, including patrolling, searching for explosives and detecting narcotics, rescuing survivors in the field, and attacking criminals targeted by their handlers (Handy et al., 1961). The interactions are primarily human-led. On the other hand, the interaction in the human-guide dog team involves more exchange of authority. Dog-led interaction is a key factor for guide dogs to perform with visually impaired owners, and both humans and guide dogs take turns to initiate actions (Naderi et al., 2001). Another study compared the performance of guide dogs with police dogs and pet dogs in an obstacle course task, where the dogs led blindfolded owners through eight obstacles. The result shows that guide dogs perform the best; police dogs perform the worst (Naderi et al., 2002). It is suggested that guide dogs are trained to be more independent by showing initiative actions regarding familiar tasks. Regarding cognitive abilities and social dependence, it is found that independent working dogs perform better with problem-solving tasks that require higher cognitive skills, and companion dogs behave more socially dependent (Topál, Miklósi

& Csányi 1998). The exchange of control between guide dogs and their handlers serves as an example of trust and sharing responsibilities.

4.5.4 Training is a two-way street

I compare the trainers training dogs to designers designing robots and robots training humans to highlight that the training is a two-way street. In the pet dog-owner dyad, Dobby demanded Sarah play with her in the morning when Sarah needed to get ready and go to work. It was not that Sarah did not enjoy playing with Dobby, but the timing was wrong; hence this behaviour needed to be changed through training. On the other hand, Dobby's behaviour also changed Sarah's morning routine. It is necessary for both parties to make changes in their behaviour to live together. Similar to dogs, robots could also bring behavioural, emotional and psychological changes. What it means for robots to be reflective is then to reflect on what human user behaviours are elicited by the social cues given out by robots. It is necessary to re-evaluate the appropriateness from a human-centred perspective to avoid undesired implications, as Sherry Turkle (1984) has warned in her book The Second Self. This leads to the idea of humans training robots, which seems to be a solution to the question of the implications caused by robots training humans. However, like dog training that there is no predetermined recipe for a domesticated user-robot dyad. The human-dog relationship is not about dominance and submission, but rather how their actions compromise and complement each other to achieve a negotiable goal. Instead, use the interaction process to reflect on the user's own activities, and behaviours. Then the question becomes, what type of robot behaviour may facilitate the reflection of the user's own behaviour. In short, robot behaviour could be utilised to encourage users to reflect on their own behaviour. There are two reasons for it; first, to avoid robot trained humans and bring humans back into the interaction, instead of humans fitting into an interactive system. Second, a potential contribution to the research methods of socially assistive robots.

4.5.5 Reflections and Limitation

This study has several limitations. While the study sampled three types of dogs and their human handlers, the sample size is limited; hence, unable to comprehend all interaction characteristics observed in this study in all human-dog interactions. While the study could benefit from a larger sample size of pet dog owners of the same demographic background of healthy retired adults, considering the little knowledge of pet dog training in China, observing dog training across three contexts is more fruitful. Jeffreys (2020) analysed governmental policy and political history of human-dog relationship in China, however, only mentioned the existence of dog-obedience training in community-based events. There are no relevant discussions of dog training experience among Chinese dog owners to compare with those in the study. The majority of pet dog owners in China are unaware of dog training services; less than 10% of pet owners used such services before 2019 (Huang, Guo and Lavoie, 2021, p.36). A tiny portion of pet owners hire home visits provided by dog trainers, for example, the pet dog-human dyad included in this study. Therefore, the study focused on finding the key difference and common characteristics across the three types of dogs in the context of training.

4.6 Summary

In conclusion, for this first study, three aspects of the human-dog interaction model are relevant to developing social robots for older adults. First, the exchange of human-led and dog-led interaction in working dogs can be useful for interaction in human-robot interaction. The leading role that is exchanged between the guide dog and human handler might be desirable in specific contexts for older adults. Second, aesthetic-oriented play interaction in pet dogs could provide entertainment for older adults. Unlike task-oriented interaction, where there is a clearly defined task to complete, play interaction is more spontaneous and requires more temporal changes in interaction modality. However, whether entertainment provided by social robots is appreciated by Chinese older adults is unclear. Third, the process of pairing and training an owner with a suitable dog together is a personalisation process and could provide a model for exploring personalisation in human-robot interaction for individuals. In the next section, I will explore the target domain concerning social robots built for retired adults for ageing.

5 Study 2: Healthy retired adults' attitudes towards assistive/social robots for ageing in China

5.1 Overview

This second study aims to gain insights into retired adults' opinions about social robots for elder care at home in China, focusing on the robotic designs' form, function, and interaction aspects. In total, 16 retired adults participated in the semi-structured interviews. All participants were physically and cognitively healthy, aged from 55 to 70 years old. Each interview lasted for 30–40 mins. Eight out of the sixteen participants are dog owners. Twelve retired staff at the activity centre of Nanjing University of Science and Technology, which the older adults attend regularly, were interviewed first. An initial reflection on the collected data suggested possible differences in attitudes towards social robots between dog owners and non-dog owners within the retired adults demographic. Four more interviews were conducted with dog owners in the same age range and in similar living conditions to understand how the experience of human-dog interaction might contribute to the design of social robots designed for ageing.

This study recruited recently retired adults instead of looking at older adults in an age group from 60 to 90. This specific demographic is selected for two reasons: firstly, a focused study of recently retired participants provides insights for healthy older adults; secondly, emphasis on retired adults frames a specific group of older adults who transition from being professionals to retired. This study conducted two sets of analyses: first, thematic analysis was applied to all participants' comments on the form, function, and interaction aspects of the robots; second, a comparison between the dog owners and non-dog owners was carried out to identify whether there are differences between the two groups attitude and preferences of social and assistive robots. Findings and discussions are presented in the last section. Quotes from participants are anonymised to evidence the findings. Lastly, a conclusion informed the second part of my practice.

5.2 Methods

5.2.1 Overview

A semi-structured interview was carried out to investigate participants' general attitudes toward the potential involvement of social and assistive robots in their retirement life. Participants were asked to comment on the form, function and interaction aspects of four different robots which could benefit them. A short demonstration video was prepared for each robot. Visual materials were collected from demonstration videos that are available online.[1] This was to ensure all participants were provided with the same information and reassure them that the interviews were not about their knowledge of each robot. I then ask the participants to share their opinions about each robot. The participants were free to choose which robot to discuss first.

5.2.2 Robots inclusion criteria

The categorisation of robots for older adults between assistive robots and personal robots is unclear. Assistive and social functions are sometimes combined in many robots' designs; therefore, both are included in the interview. It helps to get a full picture of how older adults position social and assistive functions in relation to their ageing experience, and how they see these functions fit within the care practice around ageing.

The researcher familiarised participants with four robotic designs by showing demonstration videos of each robot. The robots were included based on their forms, functions, and interaction styles (Table 2). It is assumed that by responding to robots with visual representations and information about functions, participants are able to express their attitudes and preferences. Roomba, AIBO, Care-O-bot, and ElliQ are selected to represent a wide range of robots that potentially benefit older adults by providing assistance, social interaction, and entertainment.

[1] Videos are available inside the supplemental folder submitted with this thesis.

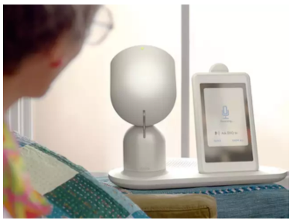
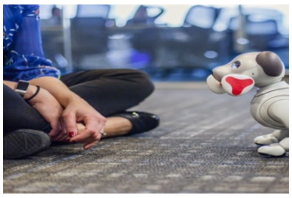
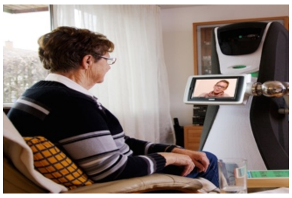
Robot	Image reference	Form	Function	Interaction style
Roomba		Object-like	Non-social assistive robot	Utilitarian-oriented: Human-led
ElliQ		Object-like	Assistive social robot	Utilitarian-oriented: Robot-led
AIBO		Zoomorphic	Companion robot	Aesthetic-oriented: Play
CareObot		Anthropomorphic	Socially assistive robot	Utilitarian-oriented: Human-led

Table 2 Robots included in the interview.

5.2.2.1 Roomba

Roomba is a robotic product that the general public in China is familiar with. It represents the archetype of labour-saving robots. Roomba is relatively small, and operates almost autonomously in a home environment. The sole function of vacuuming the floor contrasts with the other robots selected in the interviews. The following robots either offer more functions, or focus on assisting older adults in social ways.

5.2.2.2 ElliQ

ElliQ is a small stationary robot sitting on the tabletop. It has a head-like feature which could rotate and turn towards users, but the overall form is object-like. It is equipped with voice interaction and can converse with the users. Given its tablet display, it can be used as a hands-free device for video calling family and friends. It provides a range of services that are familiar to smart speakers like Google Home and Amazon Dot. It is developed specifically for older adult users.

5.2.2.3 AIBO

AIBO is a dog-like robot developed by Sony. It resembles the form of a small dog and moves on four legs. AIBO is designed for entertainment and companionship but is not particularly targeted at older adults. AIBO is equipped with its own toys to demonstrate that it can play with itself.

5.2.2.4 CareObot

CareObot is a large assistive robot developed specifically for older adults. It can move around at home and manipulate objects with its robotic arm. It is connected to a service centre, so when an older adult falls at home, the user could seek help by video calling an operator, and speaking to the person via the screen on the robot. It is the largest robot in the selected group that could be used at home.

5.2.3 Participant inclusion criteria

In this study, retirement is the main criterion over the physical condition and specific age group. Following the "turn to community", which considers the sociocultural contexts the older adults live in (Righi, Sayago and Blat, 2017). While the retirement centre has access to over 2000 older adults in the age range of 60–90, the participants were selected based on their common experience of transitioning from working to retired life, where smaller communities are brought together based on common interests at the activity centre and social actors in their lives.

In this study, in total of sixteen participants were retired within the past five years, and early into their retirement. The participants included eight females and eight males, aged from 55 to 70 years. In China, the female retirement age is 50–55, and the male retirement age is 60–65. All participants were cognitively healthy, though no formal cognitive evaluations were carried out. Eight participants were dog owners, and eight did not live with dogs or other pets.

In total, sixteen participants were recruited. The following table (Table 3) shows their age, gender, and whether they are a dog owner.

Participant	Age	Gender	Dog-owner
1	60	Female	
2	58	Female	
3	62	Male	
4	63	Male	
5	56	Male	Yes
6	61	Female	
7	56	Male	Yes
8	61	Male	Yes
9	55	Female	Yes
10	60	Female	
11	55	Female	Yes
12	65	Male	Yes
13	67	Male	
14	55	Female	Yes
15	57	Female	Yes
16	62	Male	

Table 3 Participants recruited for this research and basic information regarding their age, gender, and whether they are dog owners.

In the rest of this thesis, participants are referred to their number, followed by the letter "d" to indicate dog owner. For example, P5d means participant #5, who is also a dog owner.

5.2.4 Ethical considerations

To be mindful of the power dynamics between the researcher and the participant, a few steps were taken into the study. The information sheet clarified that the interview was not about testing participants' knowledge of robots, but their honest responses. It was anticipated that potential uncomfortable topics could arise during the interview, therefore, the researcher practiced interviews with the gatekeeper to learn about more considerate wording during the interview.

5.3 Procedure

5.3.1 Semi-structured interviews

Interviews were conducted in two phases. During the first phase, twelve participants were interviewed in person, at the Activity Centre. During the second phase, four participants were interviewed remotely via audio calls, due to travel restrictions caused by Covid-19. Each interview was audio-recorded and lasted 30–40 minutes.

All participants were informed that the interviews were conducted to learn about their general attitudes and preferences of robotic design for eldercare. All interviews started with a short warm-up regarding participants' experience with retirement and their expectations of retirement life. For dog owners, their relationship and experience with their dogs were asked before moving on to the questions about robots. Non-dog owner participants were invited to view videos of each robot, and asked to comment on each robot after each video. The researcher followed the following schedule and key questions to guide the interviews.

Interview schedule for the interview:

1. How was your trip getting here?
    a. If they have a busy social life
    b. If today is a typical day for them
2. When did you retire?
    a. How do you find retirement
    b. Any changes since retirement
        i. Adjustments
        ii. Hobbies
        iii. Future plans
3. Do you have a dog?
    a. If answers yes, advance to Questions for Dog owners (question 10)
    b. If no, advance to Question 4
4. How do you find the robot? (repeat for each robot)
    a. What's your first impression?
    b. How do you find its appearance?
    c. How do you find its functions?
        i. If they find it useful, ask the participant to elaborate.

        ii. If they find it not useful, ask the participant to explain.
    d. How do you find the way it interacts with people?
5. Which one is most suitable for you?
    a. Why?
    b. If none, advance to Question 6.
6. If you could change anything about the robot, what would they be?
    a. If yes, what they are and why?
    b. If no, advance to 7
7. If the robot is gifted to you, what do you expect it to do?
8. Would you welcome the robot now?
    a. If answers yes, please elaborate.
    b. If answers no, ask why.
9. Thank you for taking the time and sharing your thoughts. Is there anything else you would like to share that was not mentioned in the interview?
10. Questions for dog owners:
    a. When and how did your dog come into your life?
    b. What is it that your dog does you like the most?
    c. Have you ever trained your dog? If yes, why?
    d. How do you find your interaction with your dog?
    e. If robots ought to learn something from dogs, what would you recommend?
    f. Thanks for the participants, and move on to questions about robots.

Please see appendix 2 for samples of the interview transcripts.

5.3.2 Data Collection and Analysis

Interviews were audio-recorded and transcribed, and then thematic analysis was applied to the transcripts of the 16 interviews. The process started with open coding under five broad focuses: form, function, interaction, dog owners' experience, and ageing in China. In total, 267 quotes were extracted from the transcripts regarding older adults' opinions on the selected robots.

The coding of dog owners' experience regarding human-dog interaction followed the same approach and started with open coding. In total, 241 quotes were extracted from the transcripts concerning their experience with their dogs. Quotations that reflect on the opportunities and challenges of eldercare in China are categorised are coded separately in their own category.

Two broad themes are generated from the data, utilitarian-oriented rationale (see figure 5-1) and aesthetic-oriented rationale (see figure 5-2). Utilitarian-oriented rationale focuses on efficiency, effectiveness, and functionality. It also follows the framing of ageing, which focuses on the physical decline and typical robots to replace human labour. Dog owners are more open to aesthetic interaction. Aesthetic-oriented rationale recognises the potential of aesthetic interaction with social robots. This theme complements the framing of the active ageing framework proposed by WHO and works from the field of HRI that focus on robots for successful ageing (Lee and Riek, 2018).

Sub-themes were identified from both themes, including the concern over size, operation effectiveness, and voice interaction with the robots. Other categories found in form, function, and interaction are split between dog owners and non-dog owners (however, with one exception in each group of people) and correspond to either aesthetic or utilitarian interaction.

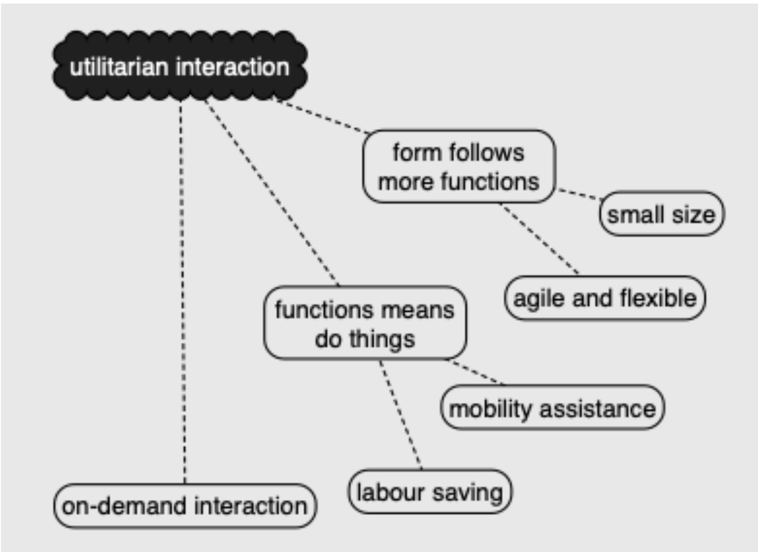


Figure 5-1. Drawn diagram based on findings of utilitarian-oriented interaction in this study.

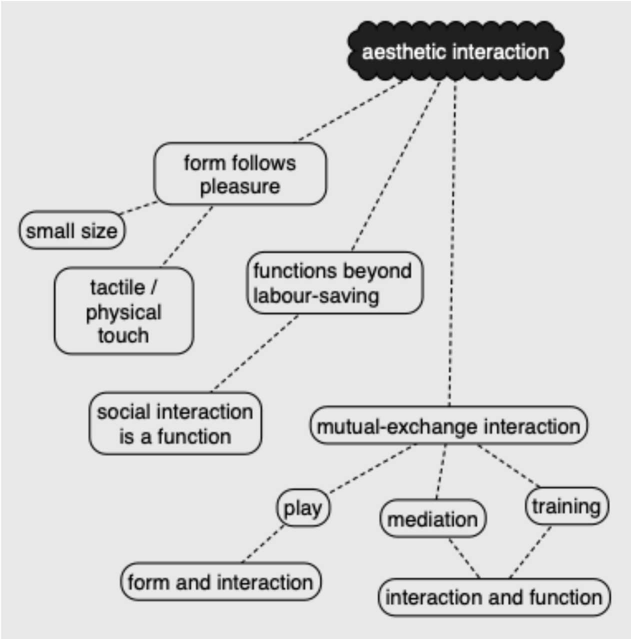


Figure 5-2. Drawn diagram based on findings of aesthetic-oriented interaction in this study

5.4 Retired adults' attitudes and expectations of socially assistive robots in China

5.4.1 Open towards socially assistive robots due to expected changes after retirement

All participants acknowledged the potential changes in physical health. One participant shared his experience with a shift of focus toward health information and personality change that come with ageing.

> Like my father, he used to care a lot about news, things that happen in the country. Now, what he cares the most is his health. (P1 2018)

All participants expressed acceptance towards physical assistance from robots if necessary. Care-O-bot (assistive robot) was seen as reactive support, which meant the older adults viewed Care-O-bot as a response to physical decline.

> This is too big, unless I can no longer move, I don't find it useful…even then, it only has very limited functions. (P5d 2018)

Social assistance and cognitive assistance (AIBO and ElliQ) were perceived as more applicable throughout the whole growing older experience. Two participants expressed that social interaction with the robot could be a means to stay cognitively active, as a preventive strategy.

5.4.2 Expecting to share and connect with service providers

All participants rejected the large size of CareObot for home environments. However, three participants suggested the potential for sharing one large size robot with more functions among a community, or a rental system that could be passed from one person to another to reduce cost.

> If there is a robot for going downstairs that's shared. For example, someone at this unit needs it; then it stays there. If a family needs to use it, it goes to that family to help the older adult to come down. (P3 2018)

Participants who appreciate the functions of robots but are reluctant to adopt them at home show a different perspective on owning a robot. This might be influenced by their experience at the retired activity centre.

> It needs to collaborate with elder care services or intuitions to run this, for example, rent out to those who are 80 years old, then get them back when they pass away. (P11d 2018)

Participants also expressed interest in integrating robots into larger systems like health services, hospitals, or local communities. Social robots at home were expected to act as an agent between individual older adults and their hospitals or health service providers. Three participants hope the robot to be part of a larger integrated health service, and share the information collected at home to share with health providers to provide more personalised service.

> Also, health monitoring is very crucial, it takes a lot of time for an older person to go to the hospital, and when you arrive, the doctor thinks it's something very, very simple, so I really hope there is some connection between the hospitals and the homes of older adults, like 'if I can stop the medicine.' I don't care that much if I don't travel, when you get older, you wouldn't travel long distances anyways. (P3 2018)

5.4.3 Robot's unique advantage: a solution to the risks of caretakers

Two participants preferred using robots because they considered robots safer than caretakers. The caretaker market in China is not yet standardised, and news regarding scammers taking advantage of older adults in vulnerable positions is a great concern for the public.

> But some caretakers, their moral compass is not…some problems are reported in the news, right? Some kidnapped young kids, some even burnt the house, many cases like these. But it wouldn't be a problem for robots. (P7 2018)

Robots were believed to be devoid of human intentions to do harm, and safe for older adults to use.

Other than security risks, Participant (P9d) expressed the advantage of robots for their potential to provide consistent and personalised care to older adults. She mentioned the quality of care was foremost important. Expressions of impatience and exhaustion from the human caretakers were inevitable.

> Older adults with strong self-respect and self-esteem would refuse to ask for help when such expressions from human caretakers are shown. This is often overlooked by care practice yet has an impact on the mental wellbeing and the quality of care they receive. (P9d 2020)

It could be a burden for older adults to ask for help if the frequency is too often or if the caretaker is less enthusiastic. Robots could offer the advantage of maintaining a consistent social interaction with older adults. Opposite to the strong bonding between her and her dog, the participant considered the lack of social bonding between a person and a robot would be liberating and inviting for the users to interact with it over a longer period of time.

5.5 The rationale for utilitarian-oriented social/assistive robots

In this theme, function is the most critical concern for older adults. Mobility assistance and labour-saving functions are most attractive for the participants. Aspects of form and interaction style are both perceived to serve the effectiveness and efficiency of the functions. The underlying assumption is that robots are used as a solution to cognitive and physical decline. Participants tend to reject social interaction with the robots, but prefer to use them when necessary.

5.5.1 A larger and softer robot is expected to perform more tasks

Participants who preferred utilitarian-oriented robots expected a large-sized robot to have a full range of functions, including mobility assistance in the bathroom, the ability to cook, and clean, and functions found on smartphones. However, participants also assumed larger robots equipped with more functions would cost more. Five participants mentioned that the cost factor is a key factor for them, and they desire something smaller to suit the home environment.

Participants expressed concern over whether the robot is flexible and gentle enough to carry out tasks including feeding, and assisting people that involve physical contact. The flexible material is seen as more agile and improves how older adults perceive the usefulness and effectiveness of the robots.

> It wouldn't be a problem for robots to do things, it's got all the strength! But maybe not soft ones; they aren't flexible. (P4 2018)

For CareObot, the rigid materials do not suggest physical contact.

> Robots are probably good at doing dishes and washing clothes, but won't be good at taking care of people, wouldn't be so delicate. (P12d 2018)

5.5.2 Mismatches of functions

All participants expressed that mobility assistance is important; however, they expected more physical assistance in specific areas like the bathroom and kitchen. Other practical functions demanded by participants were the ability to cook and clean. The breadth and niche of functions are mismatched with participants' expectations. For example, participants questioned the usefulness of CareObot to move and manipulate small objects.

> I think these simple tasks like delivering items are not important. [...] This goes back ...again...if you are really that old, to the point you can't move around, [...] if the older person is having great difficulty grabbing a glass, then I think he is probably having trouble bathing himself. (P3 2018)

Participants proposed to replace CareObot's fall detection and alert function with wearable technologies and smartphones that were much smaller than a robot.

> Wearable technologies can alert via phone or call someone, I don't need a robot to do that. (P4 2018)

5.5.2.1 Reasons for rejecting non-task interaction

Four participants expressed no interest in social interactions, and considered AIBO to be a toy for kids, or people who are cognitively declined. While voice interaction is desired by all participants, social interaction is not perceived to be a valid function.

> This one can just be a toy, maybe for these lost cognitive functions. (P4 2018)

> But maybe some kids can play with it too, with their grandparents. (P5 2018)

5.5.2.2 Concerns over the effectiveness of performance

Functions that require a physical embodiment of the robot were expected to complete the tasks with a high level of autonomy. Participants preferred treating the robots as a tool, and expected the robot to complete the tasks with few simple commands.

> Maybe when you are older and need to take many pills or supplements. But even if this reminds you, you need someone to put the pills into the right boxes. But it is helpful. (P6 2018)

5.5.2.3 Verbal conversations with a robot are perceived as useful

Participants perceived voice interaction as more convenient. Older adults who are not familiar with smartphone screens could operate a robot using verbal commands.

> And if possible, I want it to do whatever I request with my voice. (P3 2018)

> [...] maybe for those who don't know how to use smartphones, like my mother. She only knows how to make calls, so maybe ElliQ is easier since you can interact with your voice. (P6 2018)

Participants considered verbal conversation as a preventative strategy to keep an active engagement with their cognitive functions. Participants who were recently retired found the need to actively go out to meet friends, unlike previously at work.

> You need some external stimulus, yes, like speaking is just that. Our ability to speak gets worse as we get older. (P1 2018)

Participants also believed that engaging in conversations with friends is stimulating, and speaking more has both social and health benefits. However, being able to carry on a social conversation is not considered a primary function for robots.

> It should be combined with the AIBO, AIBO doesn't speak, but speaking is important. So yeh, combine them, to make ElliQ, more smart, like AIBO. Dogs are like a child of 3 or 4 years old. They just can't speak. (P2 2018)

5.5.3 The expectation of personalisation from mobile robots compared to stationary robots

While four participants expressed a preference for a stationary robot which can be placed at a fixed spot or on a surface, twelve participants preferred robots that are able to navigate the home.

Reasons for preferring stationary robots are different; while one participant worries that large robots do not have space to move around at home, others prefer to encounter the robot only when they wish to, which can be understood as an owner-initiated interaction. Participants who preferred mobile robots, suggested the robot with a dog-like attachment behaviour, where the robot follows the humans around. The robot could fade into a corner at home when the owner is busy, and come to the foreground when he needs assistance.

> It can please me, like a three-year-old child, but knows everything, also innocent. It would ask me questions like 'are you going out?', 'when are you coming back?'. For example, you are by the door and putting on your shoes, it would ask you where you are going, and when you are returning. These types of conversations, it should know. (P3 2018)

Participants who preferred mobile robots expressed that there would be potential benefits for health monitoring needs. They also had an expectation that mobility would improve the level of personalisation when a robot could learn more about the user if it followed the person.

> A robot dog would be great, then it can follow me around and alert someone if I fall, instead of installing cameras at home. (P5 2018)

In utilitarian interaction, mobile navigation of the robot was accepted if it had the purpose of improving the monitoring and gathering of personal data that can be shared with larger service providers.

5.6 The rationale for aesthetic-oriented assistive/social robot

In this theme, participants place more emphasis on the aesthetic aspects of the robots. Participants reveal diverse activities and functions that are meaningful for their ageing experience.

5.6.1 Visual and tactile qualities of social robots

Owners who came to adopt dogs expressed no particular emphasis on the form of the dogs. Instead, the size of the dog, and other qualities regarding the dog's temperament and character were appreciated.

The three formal aspects of robots, including appearance (object-like, human-like, animal-like), size and material, size is the most critical factor for older adults to perceive it as useful at home. The preference for the physical form of the robot varied; however, the participants consistently expressed a preference for a small size robot. The issue of limited physical space at home is explicitly expressed by eleven out of sixteen participants.

> If I want something to move around at home, I would prefer something small, especially when the only advantage of that big one is to deliver something to me. Otherwise, all that alerting and even contacting service providers can be done with the smaller dog one, it also moves around, and it's much warmer. (P11d 2018)

The size of the robotic dog was considered more suitable for a home environment. The mobility of the dog was believed to be more playful, and useful in comparison to a large sized robot which only provided a limited amount of physical assistance that might not even suit the needs of an individual.

Seven out of eight dog owners adopted their dogs from other owners. Mostly small sized dogs, with one exception of a medium-size dog, a border collie. Dog owners did not consider the dog-like form of the robot to be a primary concern.

In the previous theme, the material of the robot is perceived to serve the task functions. In the second theme, aesthetic-oriented interaction, soft material was desired for tactile interaction that resembled stroking and cuddling experienced in human-dog interaction.

> Maybe because I have dogs, the form needs to be better, this one seems just plastic. I want it to look like a real dog, they look too different. Maybe furs, or you can change it like clothes. If it gets on the bed, you could pet it. (P14d 2019)

This finding is consistent with older adults' preference for a robotic pet. They expressed their interest in robotic pets with warm and soft materials that they can cuddle with (Lazar et al., 2016).

5.6.2 Reasons for prioritising aesthetic interaction

Some participants placed more emphasis on aesthetic interaction and did not prioritise physical assistance for several reasons. One participant prioritised the role of a companion over assistive functions. The companionship provided by robots was not necessarily associated with loneliness; it is more to do with staying healthy and active.

> It's not that significant, if the person can't move, then what's the reminders for? Should be more about companionship. (P12d 2018)

> I think the robot dog type will be better for older adults like me who are active, say 60–80 years old could all use it, the larger ones would be more useful for those who have difficulty moving around themselves, maybe 80 years old and above. (P11d 2018)

Dog owners stressed the companionship provided by dogs, both working and pet dogs. However, companionship was usually overlooked when reducing a socially assistive robot to particular tasks and functions it performs. The ways owners interact with their dogs determine how owners perceive whether interaction could be a useful function of social robots. Owners were more appreciative of the everyday interactions with dogs that bring joy and surprise. Some owners were doubtful that the complex behaviours of robots in the future could match those of real dogs.

> The robots wouldn't have their individual characteristics, but more standardised programs. (P14d)

With these participants, the effectiveness or the number of functions provided by the robots is considered secondary.

> I don't expect the robot dog to do too much because it's only that small, but if it can mop the floor, like I can put some rags underneath its paws, that'll do. (P11d)

Participants were sceptical that a robot could have complex behaviours that bring a similar joy and surprise that are found in biological dogs. However, they also acknowledge the advantages of robotic pets. Four participants consider playful interaction with dogs more useful for healthy adults over 55 years old. In addition to its playful function, seven responses expected the robot to also provide other functions, including voice interaction, and health information from a larger network of service providers, both private parties and public sectors.

5.6.3 Interaction dynamics

Interaction and functions are closely entangled in aesthetic interaction. Dog owners' experience with their dogs affects their attitudes towards social robots. No dog owner thinks that robots or robotic dogs pose a threat to replacing dogs. Six participants, both dog owners and non-dog owners (P2, P8d, P9, P10d, P11d, P13d, P14d), expressed the potential advantages of robotic dogs.

Four participants (P8d, P10d, P11d, P14d) showed more interest in AIBO, the robotic dog. One participant with training experience (P8) expressed a strong preference for the robotic dog over other robots presented in this study. Dog owners are more attracted to the playful and companion relationship with a dog.

All participants were familiar with the companionship provided by dogs. Participants did not think robots could replicate all aspects of the experience of having a dog. Five participants mentioned the amount of care that it took to have a dog. Two participants emphasised how the constant care for dogs was different from a parent-child interaction. One participant stressed how the affection with dogs was mutual and was not to be confused with the interaction with robots. Participants spoke of behaviours that they love about dogs, which were coherent with findings of attachment behaviour and attention seeking behaviours (Konok and others, 2017).

> Because once you have a dog, you have physical contact with it. You pet it and stroke it. It has hair. And it gives you different facial expressions, and it looks at you. (P10d 2018)

On the other hand, participants also mentioned the advantages of robots that they may have over dogs in a number of ways. Four responses preferred a robotic dog because it does not shed hair and is more hygienic, so the robots could be brought onto the bed.

> It would be nice to keep a dog (AIBO). It won't shed hair. However, it doesn't seem to be able to do things...maybe as a companion, but it won't do many things. (P11d 2018)

Two responses expressed the benefit of not needing constant care, and leaving more freedom for them to plan holidays. Two participants also mentioned the life expectancy of robots could be much longer than dogs and cause less pain because there would be less emotion involved.

5.6.4 Training as an aesthetic interaction

All participants managed to train their dogs to sit and come over; however, no dog owners had experience with professional dog training, except for one participant (P8d), who had experience with formal training techniques and cooperative teamwork in hunting activities.

Only size and temperament are considered relevant in this model. The size of the dog determines what kind of work it is physically capable of. However, considering the use at home, participants prioritised the smaller size over the possibility of bigger sized robots to do more tasks. No clear preference for the appearance, material and colour of robotic dogs. For dogs, their functions are highly dependent on their physical characteristics and temperament.

In this model, the functions of dogs are defined by the owner. This model allows open space for the development of multiple functions and changes in behaviour through the interaction with the owner. Participants with formal training experience prioritise the trainability to be the primary function of the dog. Additional functions mentioned, including verbal conversation and health information, are considered secondary. For other functions like object manipulation and security alarm, the participant is confident that he can train the robot to do it.

Training is a core part of the interaction, where humans train the dog to perform certain tasks. The participant stressed the importance of being able to train the robot that is similar to a biological dog, unlike programming by writing codes. The interaction itself is considered more enjoyable, and not limited to owner-dog only. Participants expect friends to also train robotic dogs to hold playdates like robotic dog fights.

> If my friend brings over a dog, and we can compare who trained the dog better, we can have (robotic) dog fights. They wouldn't die or feel pain. That would be great! (P8d 2018)

This shows the diverse hobbies and experiences of the older adult demographic, and points out a space that is not restricted to technology hobbyists or children. Training is a form of interaction and is categorised as a cognitive game for humans.

5.6.5 The mediating role of dogs at home

Dog owners were more aware of the mediating role dogs play at home as a part of the family. Two participants mentioned the benefits of having a dog at home to improve the quality of living. The dog mediated the communication between the family members. Participant 14 mentioned how the dog would go to her mother's bedroom to ask who was distracted by watching videos and missed when she asked her mother to join the dinner from the kitchen. The task is similar to the Sunflower robot, which is modelled on assistance dogs to lead users with low hearing ability to the door (Koay et al., 2013). However, the effectiveness of modelling robots' behaviour based on assistance dogs could be extended to the social aspect of mediating communication between humans.

Another participant, who lived with her husband mentioned how the dog became a conversational starter between her and her husband and, if it were not for the dog, she might not speak to her husband for a whole day.

> [...] you have only that much to talk to your husband, wouldn't have much to talk about if without the dog. You would say things like, 'did you feed the dog? Can you walk it?' (P13d)

5.7 Discussion

5.7.1 Personalisation and new opportunities

In general, the healthy retired adults are positive towards cognitive and social assistance provided by social/assistive robots. Participants also expressed a desire to delegate housekeeping tasks for various reasons. This is consistent with the reported healthy older adults' home maintenance needs (Beer et al., 2012). In another study, Pino et al. (2015) compared the attitudes and opinions toward SARs among healthy older adults, persons living with mild cognitive impairment (MCI), and their caregivers. The researchers found healthy older adults' general preference in functionalities, including communication and socialisation, entertainment, and information. This is also consistent with the preference for cognitive and social engagements found in this study. Moreover, the researchers found personalisation to be talked about the most among healthy older adults (Pino et al., 2015). In this study, participants shared additional reasons for requiring personalisation; for example, a robot that is shared by a larger community would require the robots to adapt to new users according to their personal preferences; such robot might also need to accommodate a singular user's changes over time.

5.7.2 Dog owner participants

The aesthetic-oriented experience of human-dog interactions can be a useful model for understanding the different ways social robots complement the preventative framing of ageing found in the data. Dog owners are more open to aesthetic interaction compared to non-dog owners. Though it appears that all participants prefer a robot that is smaller and softer, their rationales behind the choice are different, which leads to a further discussion of the roles of form, function and interactions of robots are defined differently in preference of aesthetic interaction, compared to utilitarian-oriented rationale. The following findings begin to address the ways human-dog interaction could inform the design of social robots.

5.7.3 The need to mitigate the mismatch for personalised robots

A mismatch of functions is found in both themes. Participants from both themes proposed integrated service and community-based care for a positive ageing experience. All participants are aware of the possible decline in cognitive and physical condition caused by ageing. However, this is not the defining aspect of ageing, and most participants place more focus on activities they enjoy.

To mitigate the mismatch of functions, the following aspects can be considered: integration with health service providers, combined assistive and social assistance, labour-saving domestic tasks, and the effectiveness of the operation. The breadth and niche functions discussed by the participants show the importance of personalisation.

5.7.4 Reflection and Limitations

The participants in this study had no immediate care needs or chronological illness, which impacted how they perceived their needs and attitudes toward the robot. The participants may find it challenging to imagine assistive needs when they are healthy. Therefore, the data collected include what they would imagine useful for older adults.

5.8 Summary

This study gained insights into retired adults' needs, barriers, and expectations of their preferred social/assistive robots. The findings also revealed participants' preferences for the form, function, and interaction aspects of social/assistive robots. Furthermore, the findings identified two types of rationales the retired participants used in assessing their acceptance of the robot.

Utilitarian-oriented rationale prioritises the robot's functionality and form, interaction is seen as a means to achieve effective operation of the functions. Utilitarian-oriented robots are expected to carry out assistive tasks and domestic tasks. Domestic tasks mean delegating labour-saving domestic chores to robots. This is more attractive to older adults who are experiencing a physical decline in their health. Healthy older adults are less interested in delegating domestic tasks to robots for their low efficiency and effectiveness and preference for doing the work themselves.

Aesthetic-oriented rationale prioritises the robot's form and interaction; function is seen as the result of interacting with the robots. The different models of human-dog interaction suggest the multiple functions a dog could play in social contexts, which align with the idea of "role repertoires" to accommodate the changing needs and preferences (Huber et al., 2014). The previous sections show that robots can be framed as an active engagement to prevent a decline in mobility, cognitive abilities, and social connectedness, rather than as a treatment apparatus. The various models of interaction could be applied alone or combined in response to the different needs of older adults.

Practice Part 2

The conclusion of Part 1 drives the second part of the practice.

Based on Study 1, cooperative interaction found in working dogs could be mapped to retired adults' preferences over how robots interact at home. In human-led exchange, robots are expected to behave analogously to police dogs, which can execute specific tasks upon command. In dog-led interaction, where the guide dogs take more control and lead the interactions, corresponds to participants' expectation of robots being more authoritative in certain situations. For example, when the robot has more resources to complete tasks or assist human users in completing tasks, which usually requires self-discipline. Aesthetic interaction involves play is evident in all human-dog interactions. This could be an important dimension in addition to the efficiency and utilitarian aspects of human-robot interaction that should be further explored.

Robots are fundamentally different from dogs. The misconception also comes from the disembodied AI paradigm of artificial intelligence, which imagines that robots can be endowed with intelligence (as a property) and programmed to behave in specific ways. Dogs are individual living creatures with needs and want; robots are artificial man-made artefacts with no drives unless programmed by humans. Based on the findings in Practice Part 1, the process of mapping human-dog interaction to human-robot interaction revealed a space where design research could come in.

In Study 1, the pet-dog training sessions involved a trainer, a dog owner, and a dog. The role of the trainer was crucial in the training session, for having to attend many things, including getting to know the dog's individual characteristics, the owner's needs, observing the owner training the dog, and correct owner's behaviours in response to dog's behaviours. There is a gap when applying the role of a dog trainer to human-robot interaction. Roboticists build and program robots; however, trainers do not construct or programme dogs. Trainers learn the characteristics of dogs and know how to train dogs, in other words, modifying how robots behave in specific contexts. At the same time, trainers need to learn about owners' lifestyles and needs during the training.

Seeing training robots as dog training makes a few points explicit. First, training a dog is a process that involves the participation of both the owner and the dog, and often requires a dog trainer to facilitate the process.

Second, pet dog owners might lack dog training experience but understand their own needs and how they expect the dogs to behave. This information is valuable for the training process. In human-robot interaction, it is also necessary to involve multiple stakeholders to gain appropriate knowledge and resource to personalise human-robot interaction. In Part 2, roboticists and retired adults were engaged in co-design processes in Study 3 and Study 4.

Third, training means both partners have the capability of learning. What robots should and could learn in the lab and in individuals' homes remains unclear, as mentioned in the two phrases suggested by Dautenhahn in section 2.2.1. Similarly, Auger also pointed out that dogs achieved a post-utility status in the domestic environment by becoming personalised pets.

Following the three reflections above, Study 3 (Chapter 6) was conducted to understand how multiple stakeholders influence the co-design process. The study borrowed ideas from pairing and training in human-dog interaction and deployed a probe at the home of participant#2. The focus was limited to users, interaction design and technical aspects; and how they contributed to a personalisation process regarding the form, function, and interaction adaptations. Study 4 (Chapter 7) further explored how users make sense of the complex interplay between form, function, and interaction through a co-design process focused on retired adult participants' individual needs and preferences.

6 Co-design probe with roboticists

6.1 Overview

This third study aims to explore two things. First, explore the potential applications of "training together" found in human-dog interaction (study 1) by deploying a probe in a participant's home. Second, understand the positions of "research *through* design" in the development process by collaborating with computer science and robotic engineering. More specifically, whether a robot-as-dog metaphor was useful for the collaborative team members in the co-design process. This study involves two main parts. First, co-designing a robot probe with one robotic engineer and one computer scientist. Then, deploying the probe using Wizard-of-Oz at the participant's home for a week. Afterwards, the participant generated iteration sketches of the probe with the researcher's assistance. The role of metaphor in co-design is discussed in the findings, followed by insights into the robot's potential adaptations. The following section describes the procedure and methods involved in each step, including the role of making in co-design practice.

6.2 Methods and Procedure

Co-design process engages designers, participants, and roboticists throughout the process. The collaboration ran for 11 weeks between the engineer and computer scientist to develop a robot probe. Then the probe was deployed for one week of use in the participant's home environment.

In this study, the probe was a Wizard-of-Oz prototype. To differentiate the motivations behind probes and prototypes: probes are designed to provoke and elicit responses, whereas prototypes are created to manifest specific concepts and gain feedback and evaluations from users or stakeholders (Sanders and Stappers, 2014). Gaver et al. (1999) introduced a new method, cultural probe, to engage with older adults from diverse backgrounds by disseminating cameras, postcards, and maps for participants to complete without the researchers' presence. Inspired by the cultural probe, the technology probe (Hutchinson et al., 2003) was introduced with three interdisciplinary goals addressing the field of social science, engineering, and design. The method is used to improve understanding of users' needs in real-world context, field testing technology, and to inspire stakeholders to imagine new technologies. However, launching a technology (robot) probe that qualifies for field testing is not feasible for this study.

The Wizard-of-Oz technique is traditionally used to study a prototype, allowing the researchers to observe user interaction and evaluate usability problems without building a full-fledged system. In this study, the technique is applied to understand how the participant adjusts to and expect the robot to adapt at home, as part of an iterative process.

This study was carried out in four steps (figure6-1). The diagram shows the involvement of the retired participant and the roboticists in this study:

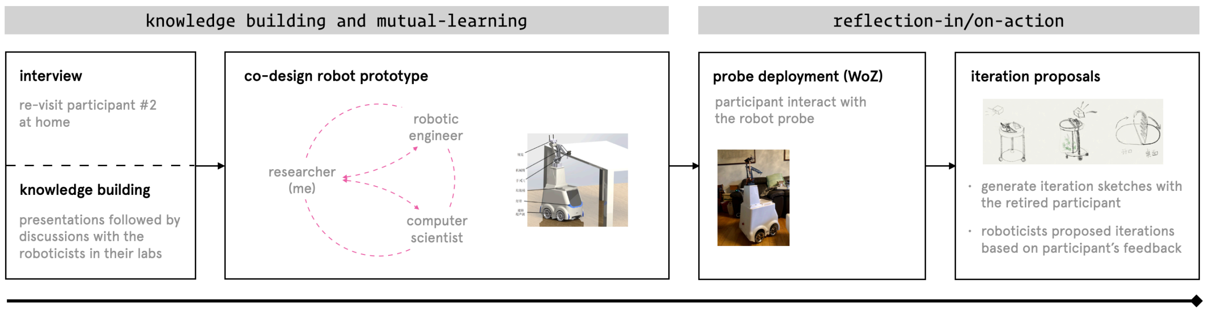


Figure 6-1 Procedure of Study 3.

1. The researcher revisited the participant at her home to discuss her latest retirement life in depth. Then, the participant and the researcher generated a potentially valuable robot concept.
2. The researcher engaged with robotic engineer, Dr Zhang and computer scientist Dr Ma as co-designers to further develop the robot concept into a prototype/probe for eleven weeks. This step involved activities such as establishing a collaborative mindset, knowledge building, and discussions on the use of metaphor, which are detailed in the following sections.
3. After testing the robot prototype in the lab, the robot was deployed at the participant's home using Wizard of Oz for a week. During the deployment, the participant shared feedback about the interaction on the day with the researcher via messages. The feedback was then shared with the roboticists to make iterations of the robot probe.
4. The researcher engaged the participant to reflect on the interaction and then generated an iteration sketch showing how the robot should be changed to accommodate the participant's needs.

Through reflections on the co-design process, the role of the robot-as-dog metaphor was discussed through reflective design documentation (Dalsgaard and Halskov, 2012).

6.2.1 Revisiting retired adult participant's background

Participant #2, Mrs Z, has recently retired at the age of 55. She lives with her husband in a flat near to the activity centre. After she retired from the university's hospital, she signed up for yoga and dancing classes at the community activity centre. The lessons keep her busy during the week. The participant also practices dance moves with her classmates regularly during the afternoons before attending the classes. She never owned a pet or was interested in having one in the future. She is passionate about keeping house plants and aims to cultivate more hobbies to stay active after her retirement.

In this study, the researcher visited Mrs Z to follow up on her experience after retirement. By visiting the participant's home, the researcher gained information about the size, spatial arrangement and style of furniture, and activities at home. An informal interview was conducted during the visit to discover potential changes to Mrs Z's retirement life. The participant enrolled in a photography interest group and started learning how to use photo editing software. The researcher asked about the participant's injury mentioned in study 2 and learnt that the participant could not carry the water bucket from the kitchen to go around the house to water her plants. While the husband was able to water the plants for her, watering plants twice daily has been a routine for the participant for the past twenty years. She finds comfort and joy in taking care of her plants. Based on this experience, the participant spoke about a robot that could carry water for her when similar incidents occur in the future.

6.2.2 Building rapport and knowledge with the roboticists

Dr Yong Ma and Dr Zhi'an Zhang from Nanjing University of Science and Technology have computer science and robotic engineering expertise, respectively. Dr Ma's research covers social robotics and intelligent agents. Dr Zhang's expertise is in the multi-robot formation control system. In the following sections, they will be referred to as the roboticists to highlight their emphasis on the technological aspect of the robot.

To ensure the validity of engaging roboticists as co-designers, mutual learning must take place between the researcher and the roboticists. Before sharing knowledge of each discipline, the researcher explained the motivation behind co-design (co-creation) to the roboticists. Then, lab visits and presentations were arranged at the beginning of the collaboration. The researcher shared the idea of conceptualising human-robot interaction from the metaphors generated from human-dog interaction; presented findings from the first part of this research.

6.2.3 Co-designing robot probe

The purpose of the robot probe was not to come up with a working robot design but served two purposes. First, to learn about the co-design process and further understand the roles design could play in developing a robot prototype. Second, to gain contextualised insights by deploying the probe in the retired adult participant, Mrs Z's home.

After discussing with the participant, an initial robot concept was proposed. The robot concept also takes in consideration of the findings from study 2, for example, the necessity of having verbal communication skill, preference of providing both utilitarian and aesthetic functions, and concern over the performance. It was decided that a robot probe should be built with reasonable technical capability for experimentation (e.g. navigation, sound, and image). The probe was used to investigate how the participant interacted and responded to the robot in various scenarios. It was important to differentiate the probe from "interactive artefacts" that do not necessarily adapt throughout time nor learn explicit information from the user. After consulting with the robotic engineer, a robot that moves on four wheels, with the main compartment that can contain a bucket of water was proposed. It was designed to reach the height of a coffee table or a regular desk, and has an adjustable tray to carry small items. A robotic arm was also added to increase the objects that the robot could manipulate in physical space. A camera and a speaker were installed behind the robotic arm so that the experimenter could navigate the room from the robot's perspective. During the design, the robotic engineers raised several questions, including concerns over the weight distribution while carrying water, the range of motion that the wheels need to support, and the range of objects intended to manipulate with the robotic arm. These concerns determined robotic engineer's decisions on the technical aspects of the robot concept (figure 6-2).

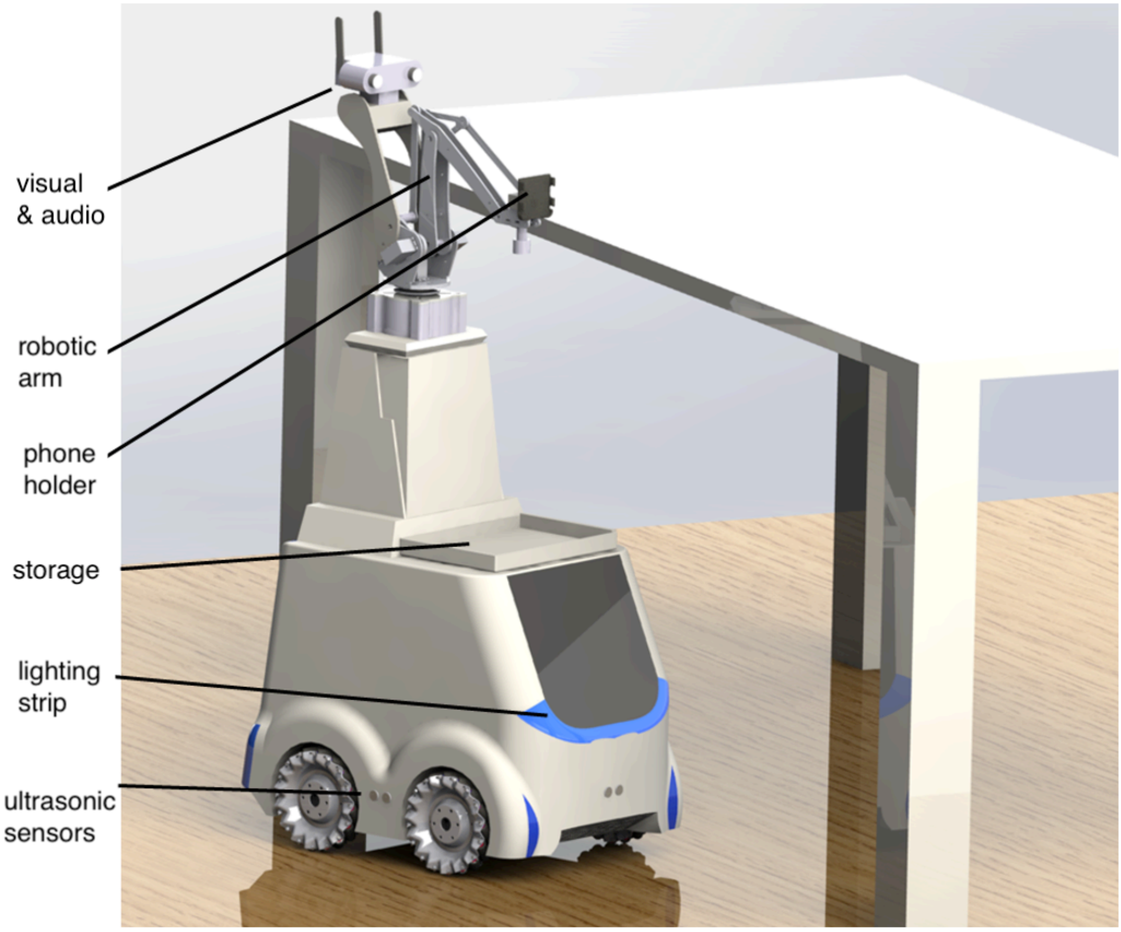


Figure 6-2 The design concept for the robot probe.

The robot can reach the height of a coffee table or a regular desk. It moves on four wheels, with a tray on the top (to deliver snacks and water). The robot can understand simple commands, listed out to users (e.g. "come", "follow me", and "stop") and pointing gestures (e.g. pointing at a person or an object, a thumb up gesture, and shaking a hand sideways).

6.2.4 Preparing for teleoperated Wizard-of-Oz

After discussing the aim of conducting an exploratory Wizard of Oz experiment with the computer scientist, a smartphone interface was developed to control the robot's movements, navigation, and speech functions. Using the interface, the experimenter observed the surrounding environment where the participant was. Audio feedback was also received and sent through the speaker on the robot via the interface.

The aspect of pairing and training together assumes a mutual capacity to learn, and a joint learning process involves both the robot and the human. The Wizard of Oz technique consists of the experimenter acting as a wizard behind the system and simulating the functional experience that the participants could experience. It allows the experimenter to gain insights into the interaction at a low cost. In this study, the experimenter simulated the robot's navigation, behavioural, and limited speech functions. The limitation of speech function was deliberate in maintaining a low expectation of the participant. Moreover, the limitation imposed on the speech function allows the experimenter to give timely and consistent responses.

The researcher played the experimenter's role and controlled the robot's behaviour via an app on an android phone. The interface allowed the experimenter to navigate the space and control the robotic arm using two graphic interfaces. The first interface (figure6-3) included a live feed that allowed real-time observation of the environment, and the virtual controllers allowed easy navigation at home. The control panel was accessible by clicking the live feed. The second interface (figure 6-4) controls the robotic arm's precise movement to grab physical items. The microphone is accessible on both interfaces. The experimenter can mute or unmute the audio feed by pressing or releasing the button.

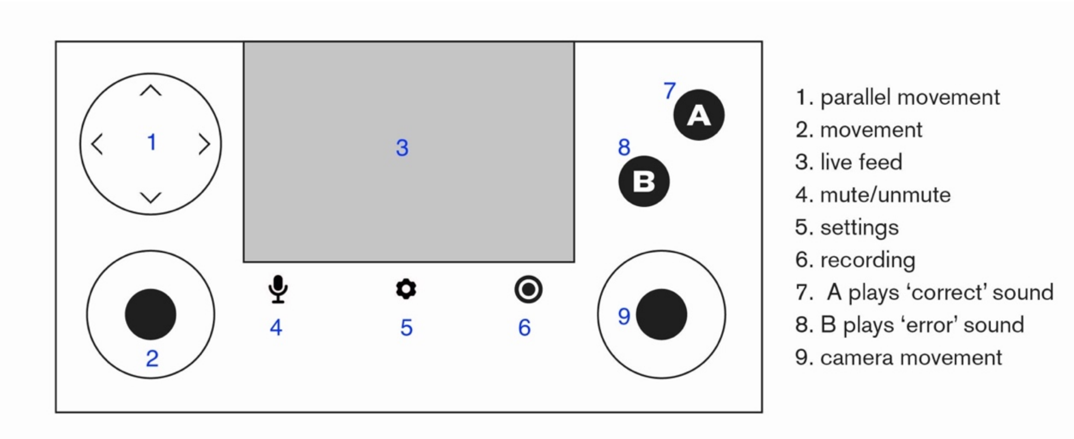


Figure 6-3 The interface for controlling the robot to navigate at home.

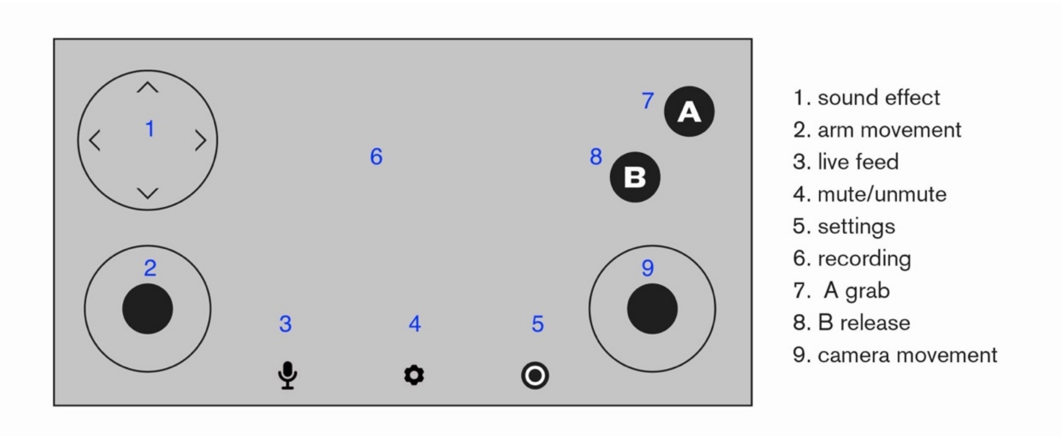


Figure 6-4 The interface for controlling the robotic arm to manipulate objects.

6.2.5 Deployment of the probe with retired participant

The researcher brought the robot probe to the participant's home and walked her through the robot's components (figure 6-5), such as the small compartment for storage and the small surface area for carrying objects. Then, informed the participant that the robot can recognise simple commands, such as "come over", and the names of the other members in the house. The robot can learn simple verbal commands that are no more than three words. During the deployment, the participant was in the living room and dining room area only, whereas the experimenter teleoperated the probe from one of the bedrooms, away from the view of the participant. The participant was not aware that the experimenter operated the robot.

Figure 6-5 Robot probe at the retired participant's home.

The robot plays two indicative sounds during the interaction to avoid unrealistic expectations of the robot. One sound was modified from the microwave's ready bell to communicate that the robot had received the commands. Another sound was modified from the computer's error sound to indicate that the robot encountered a problem. These two sounds will be referred to as the "correct sound" and the "error sound", respectively, in the discussion later (section 6.4.3).

6.2.6 Probe iterations with participants

After deploying the robot probe at home, the researcher's observations, and retired participant's feedback on the interaction with the probe was reported back to the roboticists. Then, the roboticist and the retired participant proposed iterations of the robot design.

6.3 Data Collection and analysis

6.3.1 Documentation of co-design process and analysis

The co-design process was documented using the "process reflection tool" introduced in reflective design documentation (Dalsgaard and Halskov, 2012). In this study, the process reflection tool was modified to suit the scale of the co-design process. Events were used to capture distinctive well-defined activities in the design process. Each event included a title, timestamp, description, and reflection. Notes are used to document discussions and informal parts of the design process, including timestamps, texts, and media files. The timeline facilitates Schön's idea of reflect-on-action (1983), in that one can go back to the documentation and reflect on the process afterwards.

Please see Appendix 3 for the documentation template.

6.3.2 Video recordings of probe deployment

A total of 10 video clips were collected during the one week of the deployment in the participant's home. Videos are available inside the supplemental folder submitted with this thesis.

Video	Length	Description
1	2:00	The robot moves around the household to familiarise itself with the environment. The participant did not pay particular attention to it.
2	1:10	The participant asked questions about the robot, in terms of what it is able to do. The participant explored the compartments, and understood the robot has a storage compartment, a surface tray and a robotic arm which could pick up small items.

3	2:02	A pack of snacks is delivered to the participant. The participant collected the item, but did not engage further and returned to her original task. The robot moves away from the participant.
4	2:29	The robot initiated the interaction. The participant started to talk to the robot and interacted with family members using the robot by delivering snacks.
5	3:58	The participant attempted to chat with the robot about the stock market and the weather.
6	1:56	The participant asked the robot to come, and placed a cup of yoghurt on the tray; then told the robot to deliver the snack to a family member in another room. The robot stayed still in proximity to the participant and waited for the signal [go to] and [name of the family member] to resume moving. The yoghurt was delivered, and the robot returned to its original position.
7	10:43	The participant asked the robot's intention; before the robot responded, the participant then asked the robot to bring the massage pillow but couldn't remember where it was. "Maybe it's in my master bedroom" However the room is too dark for the experimenter to navigate due to the camera's technical limitations. The experimenter steered the robot to another room, found the pillow for the participant, and delivered the item. During the interaction, the participant talked to the robot frequently. It is apparent that the behaviours of the prototype were not enough to respond nor interact naturally with the participant.
8	8:29	The participant played a casual idiom solitaire game with the robot briefly. She then engaged the robot to give opinions about the online shopping items on her phone.
9	9:02	The robot brings a tube of toothpaste to the participant after a late lunch. The participant is confused about the robot's intention and responds, "It smells good" and puts the item back onto the tray.
10	1:12	The robot moved towards the participant and tried to gain attention from the participant by moving its arm apparatus. The participant was busy and did not respond. A family member approached the participant and engaged in a short conversation while the robot was present.

Table 4 Videos recorded through the probe's camera during its deployment at the participant's home.

The video collected from the robot's video cameras were hand-coded using screen captures. The videos were annotated with context, intentions, behaviours, level of control, and verbal expressions.

After each deployment, the researcher sent out text messages to the participant for her feedback on her experience with the robot.

6.4 Findings

6.4.1 Articulating metaphors in the co-design process

During the knowledge building phase with the roboticists, the researcher shared the robot-as-dog metaphor as a unified perspective to understand the two phases described by Auger and Dautenhahn (section 2.2). Then, the designer-as-trainer metaphor and personalisation-as-training metaphor were introduced to discuss the various aspects of human-dog interaction that were potentially useful for human-robot interaction.

After gathering the latest background information of participant 2, an initial co-design phase, which resulted in the production of the robot probe, was completed with the involvement of the roboticists. The basic functions and default settings were decided, including the physical form, the functions, and the basic behavioural patterns. As described in section 6.2.3, the functions were based on the input from the participant about her health condition and experience, and roboticists' concern over technical constraints contributed to the physical form of the robot. Since the probe was deployed using the Wizard of Oz method, its basic behavioural patterns followed a protocol that determined how it behaves and interacts with the participant. After the robot probe had been placed at the participant's home, a second co-design phase started. The phase focused on how the participant makes the robot her own, in a process of integration into everyday life.

In the co-design process, it was challenging to communicate the idea of allowing users to train robots in their own homes as a form of personalisation. While all team members agreed that the pairing process could and should be done between a person and a robot, drawing a parallel with the interaction between a dog and a person, which allowed a working dog and pet dog to fit into the lives of the human handler raised questions for the roboticists. The computer scientist questioned the usefulness of transferring this analogy from dog training to human-robot interaction. I proposed that a similar training process between a human and a robot would allow the robot to learn the preferences of the human user over time and enable the user's expectations of the robot to better align with its actual abilities. However, the roboticists suggested training robots in the laboratory for a pre-defined set of tasks, so the robot could perform the tasks effectively right away when presented to the participant.

> Training at the home is unnecessary, older adults can customise the features or preference, but the robot need to be trained first, then when they customise, it simply recalls what has been trained, so it is safe (Dr Ma, July 19 2019).

Several studies started exploring how users can provide information and feedback to artificial agents, in order to improve the interaction. For example, Cruz et al. (2016) experimented with providing interactive feedback to a robot to learn the task of cleaning a tabletop. In another study, Hemminghaus and Kopp (2017) used reinforcement learning to generate adaptive social behaviour for assistive robots.

Both roboticists and the researcher agreed that the robot would need to learn about individual users to tailor how it assists and accompany the user at home. During the discussion, the team compared the human-dog pairing and training process to the customisation process, in order to articulate the possible difference between "training" and "customising". Roboticists insisted that training should not take place at home because of safety measures. Besides safety concerns, customisation suggests a pre-defined space that could be modified based on the user's preferences. This lacks what "training" implies: ongoing learning and exchange between two partners. In the deployment of the probe, if the participant were given options to customise the robot, the designer and the roboticists would pre-define the customisable space. However, training as a co-shaping process emphasises imagining how the robot and human both adapt to one another at home over time.

6.4.2 Paradigm differences found in the co-design process

The roboticists and the researcher were driven by different motivations. In this study, the participant was observed in the dimly lit living room where she was spending her time. As the experimenter was operating the robot using the WoZ method, the lighting was vastly different from the lab environment where the robot was tested with the roboticists. The experimenter documented this observation, and the robotic engineer proposed to upgrade the camera to one with a higher resolution and night vision. The issues with lighting that directly impact the ability of the experimenter to carry out experiments are likely to be framed as a technical problems. The suggestion of a hardware upgrade was an example of a technology-centred approach. On the other hand, it is worth considering the physical/technical capabilities as a space for exploration. The difficulty encountered as a wizard behind the scenes prompted another approach, considering the possible actions a robot could take, and how humans would understand the meaning of the action. For example, would the robot be authorised to turn on the light itself? Which is more obedient if a dog and a robot both turn on the light in a room when humans sit in a dim lighting environment? The latter used the robot as a probe to explore the interaction possibility in response to the technical limitations of the robot probe. Another study also addressed the physical limitation of the robot's embodiment and explored the possibility of moving a robot persona across different robotic bodies to fulfil tasks that require different physical forms (Luria et al., 2019).

In most previous studies, the robots were deployed as prototypes to test whether the prototype was effective for defined tasks; the focus was often placed on usability testing. In such cases, the emphasis is placed on advancing technology and automation. This study highlights the paradigm tension between the disciplines involved in the designing process of a robot. It is useful to clarify whether a robot is a prototype or a probe. When the robot is treated as a probe, the researcher's response to any technical limitations is to open a space for interaction design.

6.4.3 Participants' interactions with and mediated by the probe

The participant showed curiosity after the robot had moved around in the home. She also explored the compartments of the robots. After the first delivery initiated by the robot, which brought a snack to the participant, the participant tried to deliver a snack to another family member using the robot. The participant placed a cup of yoghurt on the tray and communicated the task via verbal commands. Once the robot started moving, the participant notified the family member that the robot was coming to deliver a snack with a louder voice. This talking over was unexpected before the deployment of the probe in the environment. The participant talked to the experimenter as a family member while the robot was moving toward the experimenter.

Though the robot had no facial features like eyes, the participant turned her gaze towards the camera on top of the robot arm. The participant used a higher-than-normal voice and communicated to the robot with more questions in a gentle tone as if she was talking to a young child. However, when the participant addressed family members in real life, her voice returned to normal. Weiss (2010) suggested that WoZ controlled robot is more human-human interaction than human-robot interaction. In this study, the participant's higher speaking tone in video 4, in contrast to her normal speaking tone in video 6, suggests the retired participant differentiates her communication with the robot from via the robot.

Based on the participant's verbal interaction with the robot and the family member, a new functional feature was improvised with the existing audio channel on the control platform. Afterwards, the participant was informed that the robot could also be used as a platform to talk to another family member, by saying "call" and the [name] of the person, to activate a real-time audio call. The participant differentiated whether she was talking to the robot or a person at home. However, this new feature influenced how the participant interacted with the robot. After speaking to a family member through the robot, the participant expected the robot to speak as well.

When the participant asked questions that the robot could not answer, the experimenter remained silent and expressed the robot's inability to engage in conversations that require judgement by pressing the "error sound" and turning the robotic arm facing away from the participant. Without verbal expression, relying on the movement and direction of the robotic arm and audio signal, communication possibilities were minimal. While the participant was cooperative and tried to understand the robot's intentions by asking simpler questions, she expressed confusion between the "platform" and "actor" roles played by the robot.

> I know I can talk to a person using this robot like a phone, but I don't remember what it knows or what it can say, so I just talked to it...then I get confused and talked to it sometimes as if it's a person. (P2 2019)

In video 8, the participant initiated an idioms solitaire game. In this interaction, the experimenter responded to the participant. The idioms solitaire game is a traditional Chinese game that consists of taking turns to speak out idioms. The rule is that when one person finishes their idiom, another person has to respond with another idiom whose initial letter is the same as the last letter of the previous idiom. If a person fails to continue, then they are considered to have lost the game. The experimenter decided to engage with this game during the interaction because it was a plausible social game that the robot could play, utilising currently available natural language processing and machine learning skills. This knowledge was gained during the knowledge building in co-design process (described in 6.2.2). It is assumed that the robot can outplay the human because of its capacity to store and recall information. After a few exchanges, the participant could not think of an idiom. She returned to browsing for online shopping on her phone, asking challenging questions for the robot to answer (e.g. what the robot thought of a product she wished to purchase online).

> This robot, a smart…thing, I don't know what else (it does) besides driving around in the flat, but it beat me at the game! I like how it played games with me, a little light exercise for my brain. But it doesn't know anything about stock market or what looks nice… (P2 2019)

The solitaire game could be seen as an example of aesthetic interaction in which efficiency was not the aim of the interaction (Petersen et al., 2004). On the other hand, the interaction was characterised by its playful nature, and engaged the participant's cognitive skills and emotional values (ibid). The use of audio signals and limited verbal skills through the Wizard of Oz method suggests that the participant expected the robot to have a cognitive capacity that would enable it to converse with her, and greater knowledge of subjects that she was interested in, for example, the stock market. Verbal communication skills seem necessary for both utilitarian and aesthetic interaction.

6.4.4 Negative attitude toward unintentional sound

The participant complained about the noisy movement of the robot, which is not suitable for the home. The sound was caused by the omni-directional wheels, which were chosen to enable the robot to move in any direction and across different surfaces. However, the sound instantly evoked a sense of a large machine due to its volume.

> It is too loud for the home, it's like a little train. It's good that I can hear it, so I know it's coming, but it is annoying when it moves a lot (P2).

This suggested a need to revise the locomotion mechanism to improve the user's perception of the robot for the home environment, and to test this across different surfaces. The omni-directional wheels were selected for their agility and tested in the laboratory, which had carpet floors; however, the volume of the noise became significantly louder on the participant's wooden floor. Sound plays a significant role in human-robot interaction. However, only a limited number of studies have explored acoustic aspects, such as the unintended sound caused by the mechanical parts of robots.

The unintentional sounds are what Frid, Bresin and Alexanderson (2018) call "consequential sound", generated by the robot's mechanical movements. Moore et al. (2017) studied the correlation between the sonic properties of servo motors and the subjective experience of users. The study surveyed participants' perceptions of 20 servo sounds that are commonly used in robotic prototypes and found that such sounds were overall rated negatively. Robots' presence and quality of inherent mechanical sound influence users' perceptions. Another study of a robotic arm found that, although the social context of the interaction generally increased "the perceived competence, trust, aesthetic, and human-likeness of the robot", all mechanical sounds reduced the robot's human-likeness (Tennent et al., 2017). In short, more attention should be paid to the unintentional sounds of robots and the implications of the sonic dimension during interactions.

6.4.5 Re-purposing of functional features

Though the participant was aware of the water tank function of the robot, the participant engaged more with the manoeuvrable side table function of the robot, and not the water tank function that was ideated initially. The participant was able to exchange snacks with family members and instructed the robot to fetch items for her, but found limitations in its main functionality.

> I'm recovered now, so I don't think it's that useful right now, maybe if I fell again...but the water tank is so small, I can only water two planters at the most...but if it handles more water it will need to be bigger right? (P2 2019)

The participant tried to make alternative use of the water storage compartment to store other objects; however, it was too deep for her to retrieve the items. Singular functions are limited to specific conditions, and often depend on the short-term physical conditions of the participant. The participant decided that the functional feature could be useful under the right circumstances. However, finding it not useful at the time the study is conducted.

> I didn't know what it wanted...so I sent it off to get the massage pillow. (P2 2019)

In the reflective discussion with the participant, the participant spoke more about her routine with houseplants throughout the seasons, which revealed new opportunities for the robot. Previously, the probe was designed to address her back injury. However, the focus shifted to her activities at home during the reflection. The researcher assisted the participant in iterating the robot concept using sketches (figure 6-6).

Figure 6-6 Iteration sketch of the initial probe design.

The new concept was an adaptation of the initial concept in relation to form, function, and interaction style. The modifications were partly based on the feedback and insights gained from the participant's interaction with the probe. In the sketch, the storage was repurposed to function as a garbage bin for pruning leaves during the growing season. The bottom space could also carry larger or heavier items like a water bucket. The top tray was iterated into a flip opening that can accommodate different use scenarios. The rationale behind the iterated concept was that the robot would blend better into the home, and its lack of physical manipulation function would be more adaptable. Other socially engaging functions, like conversations, would be fulfilled by a smartphone. The participant found it more practical to remove the robotic arm and replace it with a docking station for her tablet or phone.

The participant welcomed interactions initiated by the robot as the robot's movement sparked curiosity and gained attention from the participant; however, she preferred more clarity in terms of its intention.

6.5 Discussions

6.5.1 Use of metaphor in an interdisciplinary co-design process

In this study, the iterative co-designing process of the probe presented both benefits and challenges during which could provide insights for future interdisciplinary collaboration. Höök and Löwgren (2012) pointed out the role of mediated communication in the collaborative production of knowledge. They described how the process of knowledge production in a scaled-up community would require what Krippendorff (2006, p.31) calls the languaging of design. By reflecting on the collaborative process, the study focused on analysing how each discipline engaged with form, function, and interaction adaptations in the collaborative process of knowledge production.

In a previous study, the researchers found older adults responded to the computer-as-a-dog metaphor better in the case of robots failing to understand human participants (Albinsson and Forsgren, 2005). By changing from a humanoid avatar to a cartoon dog avatar, the participants talked in short sentences and became more tolerant of the robot's competence. The study also suggested that using dog avatars was easier for users to select different types of dogs, imaging the actions and services each type of dog can perform.

Through the co-design process, team members were able to learn the technical and user aspects involved in human-robot interaction. The concept of the probe was considered key for the team to work together; therefore, the technical requirements for the robot - whose emphasis is on computing and engineering - did not lead the study; rather, equal emphasis was placed on interaction design after establishing a common understanding about using a probe to explore user scenarios in the home environment.

For example, the form was proposed by me, the designer, and modified based on the engineer's concerns over time and cost. The form was the result of a compromise to accommodate the cost and the development time set for this study. On the other hand, affordable robotic arms were commercially available and simple to integrate into a robotic system; however, the range of the object that the robotic arm could pick up was often overlooked in a non-technical study. Factors including size, surface texture, the hardness of the object, from which angle the object could be picked up, etc., are all contributing to the effectiveness of the robot arm. In a home environment, this is particularly important because of the diverse range of objects a person might require the robot to pick up. Moreover, robotic arm forms and weight have a wide range; the gripping system could also influence its performance. All of these influence how human participants in the study could interact with the robotic arm. This technical limitation is challenging for robotic and interaction researchers in their own right; however, this study responded to the technical limitation of the robotic arm by exploring its possibilities, rather than solving it. Instead of treating the technical limitations of the robotic arm as an unavoidable factor to consider in human-robot interactions, the study points to research spaces that emphasise the contexts and humans' interpretations of and responses to the situation.

6.5.2 Training: a user-led process

In this study, the participant's interaction with the probe showed how the robot should be personalised through form, function, and interaction adaptations. There is a lack of change in the robot's physical form in previous studies, except for one study that addressed the space for meaningful alternations of robot's forms through 3D printing and knitting technology for personalised customisation (Colle, 2020). In this study, ageing is seen as a process. The participant expected the robot to accommodate the changes in her physical health. Instead of a unibody design, the participant proposed a modular system with robotic parts that can bring convenience and assist at home more effectively.

Personalisation and customisation differ on who takes control or leads the process. In other words, personalisation is implicit, and requires no active input from the user but requires data and algorithm to make modifications; customisation is explicit, and dependent on the user's conscious input. Sundar and Marathe (2010) investigated the roles of tailored experience and sense of agency in the appeal of customisation (as a result). Their study revealed that power users prefer customisation, whereas novice users prefer personalisation. In this study, training together was used to articulate a human-led process that blends personalisation and customisation in context. Though the participant had not been a power user of any robotic device, the iteration sketches showed a desire to "customise", for it to function effectively for her personal needs.

Customisation implies a finite space that is pre-defined by designers and roboticists. Training emphasises an aesthetic experience that "invites people to actively participate in creating sense and meaning" (Petersen et al., 2004). Apart from appealing to users' preferences over how a robot looks, a modular system of the physical form can better fulfil users' diverse needs. Robots' functions should be situated in the participant's environment and understood according to a robot's use in a task or activity. Furthermore, interactions with the probe reveal aspects related to the interaction's aesthetics with robots that require further exploration. In other words, the modular robotic parts should maintain a level of ambiguity for users to define in their user contexts. This could improve the sense of control and perception of usefulness.

6.5.3 The need for a modular robotic system

The iterated sketch shows that the robot resembles familiar domestic objects, like a piece of furniture, which are more welcomed. More importantly, the outcome suggests a modular robotic design that allows users to modify its form to fulfil multiple roles and accommodate changes over time. Modular robotic designs have been proposed in other fields of applications for the unique shape-shifting ability. In a recent review of the latest development of modular, reconfigurable robots, Seo, Paik and Yim (2019) reported the advantages in areas of versatility, robustness, and low cost are yet proven; moreover, the researchers pointed out the necessity of fulfilling all three aspects simultaneously for real-world applications. In a recent study, Hauser et al. (2020) presented a series of self-reconfigurable modular robots, Roombots, that equip existing furniture to move around, and provide simple object manipulations. The Roombots can also self-configure multiple modules into a toy, and are capable of interacting with human hand gestures. The participant's desire for a modular system that resembles furniture is very similar to the development of assistive and adaptative furniture. Apart from the unique versatility of shape-shifting robots, supporting a user-led robot configuration may result in the following benefits. This is consistent with findings in Study 2 (sec 5.5.2), three participants (P3, P6, P9) expressed their concerns over mismatched robots' functions shown in the interview, and suggested to combine different functional features or/and formal elements from AIBO, ElliQ and CareObot to satisfy their needs for cognitive and physical support over foreseeable years. It is evident that modular system could also mitigate the mismatch of functions. Moreover, four participants (P2, P4, P14d, P16) mentioned their concerns about cost-effectiveness. A modular system that can be reconfigured into fulfilling more tasks is likely to be perceived as more cost-effective than unibody designs.

6.5.4 Reflections and Limitations

Several limitations to this study should be acknowledged. While the computer scientist is familiar with social robotics and intelligent agents, the robotic engineer focuses on robotic vehicles and multi-robot formation control systems. The effect of roboticists' expertise in assistive robotics in the co-design process was not evaluated. This study separately engaged the roboticists and participants to focus on the applicability of the designer-as-trainer metaphor identified in previous studies. This limited scope allowed knowledge building and relevant field of interactive reinforcement learning.

The videos were recorded using the camera on the probe; therefore, the videos did not capture the robot's behaviours from a third perspective. Instead, the camera provides a unique first-person viewpoint. This may have implications for the experimenter's execution of WoZ deployment.

During the discussion and feedback sessions, no question explicitly addressed participant's attribution of robot's gender identity. This remains unclear because, first, the researcher's voice was manipulated through the sound quality which may not have a clear indication of gender; second, the participants did not raise questions about gender in her self-reported feedback sessions. Moreover, in spoken Mandarin, he/she/it are all pronounced as "tā. In English, it is almost impossible to refer to any person, animal, or robot without attributing a gender. However, while he/she/it are all pronounced the same. It is culturally appropriate to refer a pet or an object as "it". Therefore, gender becomes less of a concern in comparison to spoken English from both phonetic and conceptual perspectives. The findings suggest that gender is not a primary concern, considering the participant's raised voice during interaction with the robot (described in sec 6.4.3), and how she referred to the robot as a "smart thing" in the discussions. In Sørra's study, this difficulty of not gendering robots in Western language is also recognised, and she shows how gender can be less important than Japanese (2017).

Participant's conception of the robot being a "thing" and a "helper" rather than "pet" may be influenced by the robot's non-zoomorphic appearance and verbal communication ability improvised later in the interaction. Unlike working dogs that utilise gadgets (e.g. harness described in sec 4.4.1) to cooperate with handlers to complete tasks, the companion role is the primary value of pet dogs. The "smart thing" perception distance itself from the companionship role, and freed from the physical embodiment limitation of a pet dog. This is evident in the modular system idea depicted in sketches generated by the participant in sec 6.4.5. Furthermore, the short deployment time did not give ground for the participant to develop any relationship with the robot.

6.6 Summary

In this chapter, I described the usefulness of engaging metaphor to articulate the roles that users, interaction designers and roboticists could play in the co-design process of a probe. Then, the deployment of the probe at the participant's home revealed a few insights about how form, function and interaction adaptations could be explored in a "training" process.

The study analysed the usefulness of articulating the details embedded in metaphors used in the co-design process within a multidisciplinary team. The metaphors were used as a communicative tool to articulate the implications of emphasising particular disciplines and facilitating the co-design process discussions. The findings show that conceiving of "training" facilitated discussions of collaborative work between the roboticists and design researchers. The team members could articulate which aspect to focus on, whether a technical hardware upgrade was enough or iterating the design concept would be more fruitful. In this study, the technological limitation of the robotic arm and the camera provided examples of how a technology-centred approach differs from a design research paradigm.

Design research methods complemented a technology-centred approach, which treated the technical limitation of the camera as a usability issue to be solved with a hardware upgrade. In this study, recognising the camera's technical limitation was a turning point; instead of upgrading the camera as the ultimate solution, the study carried out sketching with the retired adult participant to iterate the functional features, form and interactions with the robot. A hardware upgrade would be useful if the robot were treated as a prototype in the study. It missed the opportunity to recognise the question of technological limitation, by engaging the participant to reflect on her interaction with the robot probe using pencil sketches to make iterations on the probe in terms of form, function, and interaction in her personal life. The following study explores the participants' sense-making of robot concepts in contextualised scenarios.

7 Co-design robots with retired adults

7.1 Overview

This final study investigates the role that form, function and interaction aspects characterising the human-dog interaction might play in retired adults' interaction with social robots. There was no intention to replicate a human-dog companionship to begin with, but the cooperation and training process between the human and the dog in different contexts (detailed in sec 4.4.4 and sec 4.4.5). In addition, study 3 (suggests that 'personalisation as training' promotes an aesthetics of use that engages participants to personalise robots' form, function, and interaction aspects. This study spanned before and during the Covid-19 pandemic; hence some of the original methods and processes were altered to conduct remote research (section 7.2.2). Eight retired older adults participated as co-designers to engage in an iterative process. The process included a 'discussion' phase, a 'drawing together' phase, and a 'storyboarding' phase to understand how the contingent conditions (personal factors) shaped their concept of a robot around form, function, and interaction style. Then, I took an interpretative stance to analyse the materials produced during this co-design process with the participants and revealed the reasoning behind retired adults' iterative designs of assistive/social robots concerning the form, function, and interaction style aspects of human-robot interaction to fulfil their individual needs and expectations. The findings add to the understanding of the complex synergy among the three key aspects from the perspectives of retired adults. The interest lies in whether any differences between dog owners and non-dog owners would reveal the relevance of dog-human interaction as a metaphor for human-robot interaction. Findings from each workshop are detailed in the following sections, showing additional factors that influenced retirement adults' social/assistive robot concept sketches.

7.2 Methods and Procedure

7.2.1 Participants

Eight older adults between the age of 55 and 70 participated in the study, including four who had experience with dogs and four who did not. They were participants recruited previously from Study 2. All participants had access to the internet, a tablet, or a mobile device. The participants were familiar with essential functions on their smartphones; and able to navigate the online co-creation space designed by the researcher.

Participant	Age	Gender	Dog-owner
1	60	Female	No
2	58	Female	No
7d	56	Male	Yes
8d	61	Male	Yes
9d	55	Female	Yes
13	67	Male	No
14d	55	Female	Yes
16	58	Male	No

Table 5 Participants in this study.

7.2.2 Procedure and materials

Due to COVID-19 travel restrictions, the original plan for a face-to-face study had to be altered at short notice. A new set-up was developed to conduct the study online using a collaborative whiteboard via participants' mobile devices. Each participant was invited to participate in three workshops. The whiteboard platform allowed participants and the researcher to draw and write in real-time using their fingers. Each whiteboard included nine pages, with pre-designed visual elements and textual information.

A link was generated and sent to the participant two days before the session to ensure they could access the whiteboard space with their personal devices. The participants were also invited to draw something they enjoyed on the day using the whiteboard before the workshop. Each workshop lasted 30–40 minutes long. The researcher called the participants via audio call on WeChat and recorded the discussions in real-time while drawing on the whiteboard. Specific techniques used include ideation, sketching, and storyboarding were used to envision robots that would address participants' personal needs.

7.2.2.1 Workshop 1: Ideation (interplay between form and function)

This scenario involved two robot concepts with different embodiments but provided mobility assistance, helping a person move from the bed to a wheelchair at home to investigate which form is preferred by the participants. This function was selected based on retired adults' consensual acknowledgement of mobility assistance being useful in Study 1 (sec 5.5.2). The hypothesis treats the mobility assistance function as a constant, and the form as a variable; therefore, participants' choices can then reveal how retired adults articulate the relationship between form and function.

The first robot concept created by Lirong Yang (figure 7-1) utilises a convertible design that brings a bed and a wheelchair into one. When part of the bed is folded up, it transforms into a wheelchair. It is convenient for users to move from a bed to a chair without heavy lifting. The second robot (figure 7-2) is a bear-shaped nursing robot that can lift and carry users from the bed to another place (i.e. a wheelchair) using robust and padded arms. To compare form and function, participants were shown the robots' images and asked to choose their preferred one to carry out a mobility assistance task and their reasons for the choice, followed by a discussion about the robot form, regarding its size, material, and facial features.

Figure 7-1 LOHAS by Lirong Yang.

Figure 7-2 RoBear by Riken and Sumitomo Riko Company.

Lastly, participants were invited to describe or draw an ideal robot and talk about their sketch. Being mindful that participants with limited experience with robots can find imagining a robot challenging (Lee et al., 2017), the whiteboard space included examples of possible materials to encourage participants' participation.

7.2.2.2 Workshop 2: Sketch (interplay between function and interaction style)

After the participants made their initial sketches of their ideal robots, the researcher explored the relationship between functions and preferred interaction styles through co-designing scenarios with the participants. According to Bødker's differentiation between open- and closed-ended scenarios (workshop 3). This workshop focus on open-ended scenarios. The motivation to construct a scenario was "1) to present and situate solutions; (2) to illustrate alternative solutions; and (3) to identify potential problems" (2000).

To begin with, the participants were given a list of functional features which they could choose from (e.g. reminders, alerts, news) to discuss with the researcher. Subsequently, based on the findings of Study 1 (Chapter 4), the researcher introduced three interaction styles, namely autonomous, human-led, and robot-led. Participants were asked to select interaction styles with their chosen functional features, and sketch scenarios with the researcher's assistance. Examples of interaction based on workshop 1's material were provided to lower the barrier for the participants.

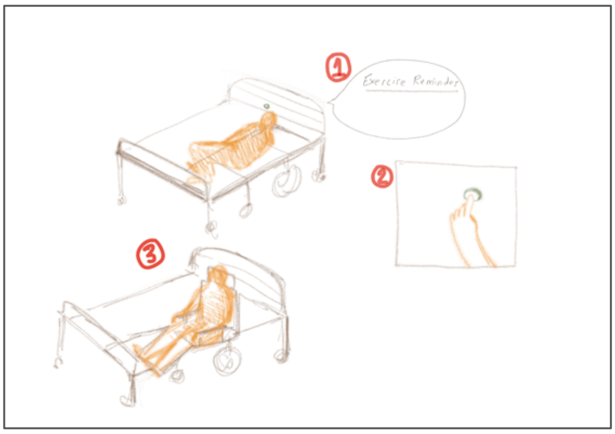


Figure 7-3 Interaction of bed-wheelchair robot.

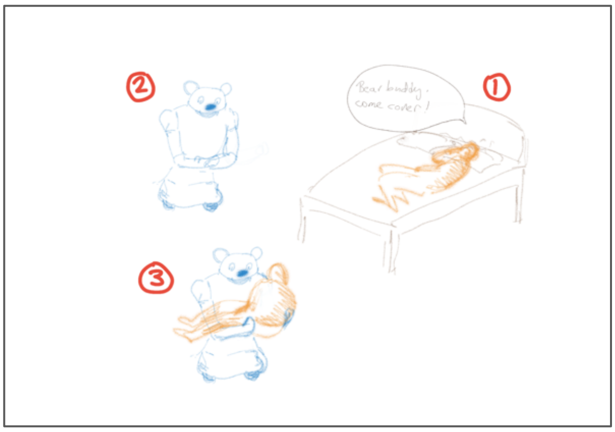


Figure 7-4 Interaction of robot bear.

7.2.2.3 Workshop 3: Storyboard (interplay between form and interaction)

This discussion involved two robot concepts: a furniture-like robot (figure 7-5) that behaved 'like a dog' (i.e. it shows attachment behaviour and follows human gestures); and a dog-like robot (figure 7-6) but behaved 'unlike a dog' (i.e. it executes commands autonomously); in order to investigate whether participants gave more importance to the form or the interaction style of the robot.

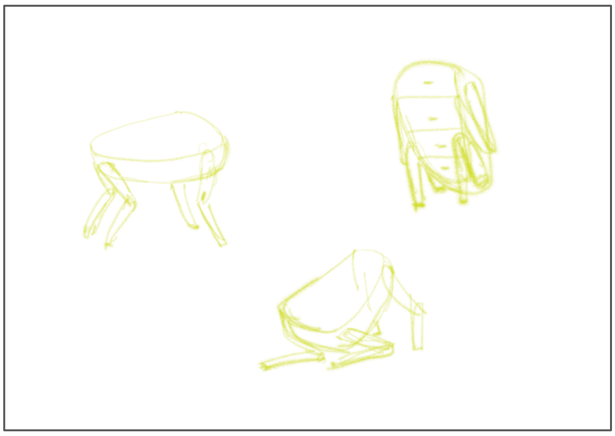


Figure 7-5 This robot resembles a chest of drawers. It could be used as a side table when it stands still. It can navigate on its four legs.

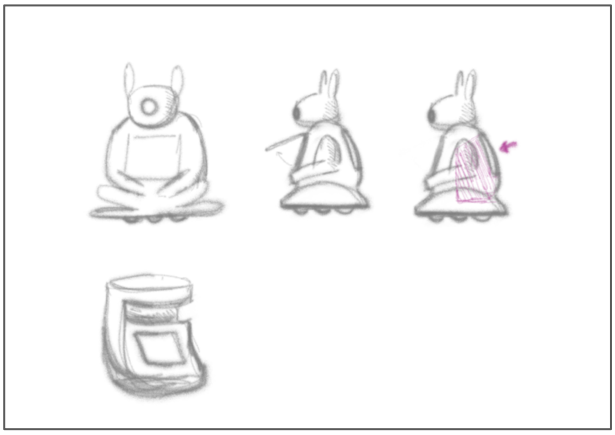


Figure 7-6 Sketch of a zoomorphic robot with a screen and compartment for storage.

Participants were asked to choose a preferred interaction style between the two robot forms and talk about why they chose one over the other. Participants were shown a digitally rendered scenario set inside an apartment (figure 7-7). According to Bødker's distinction, this was a closed scenario (2003), whose function was to prompt participants to reflect on how they perceived the interplay between form and interaction style.

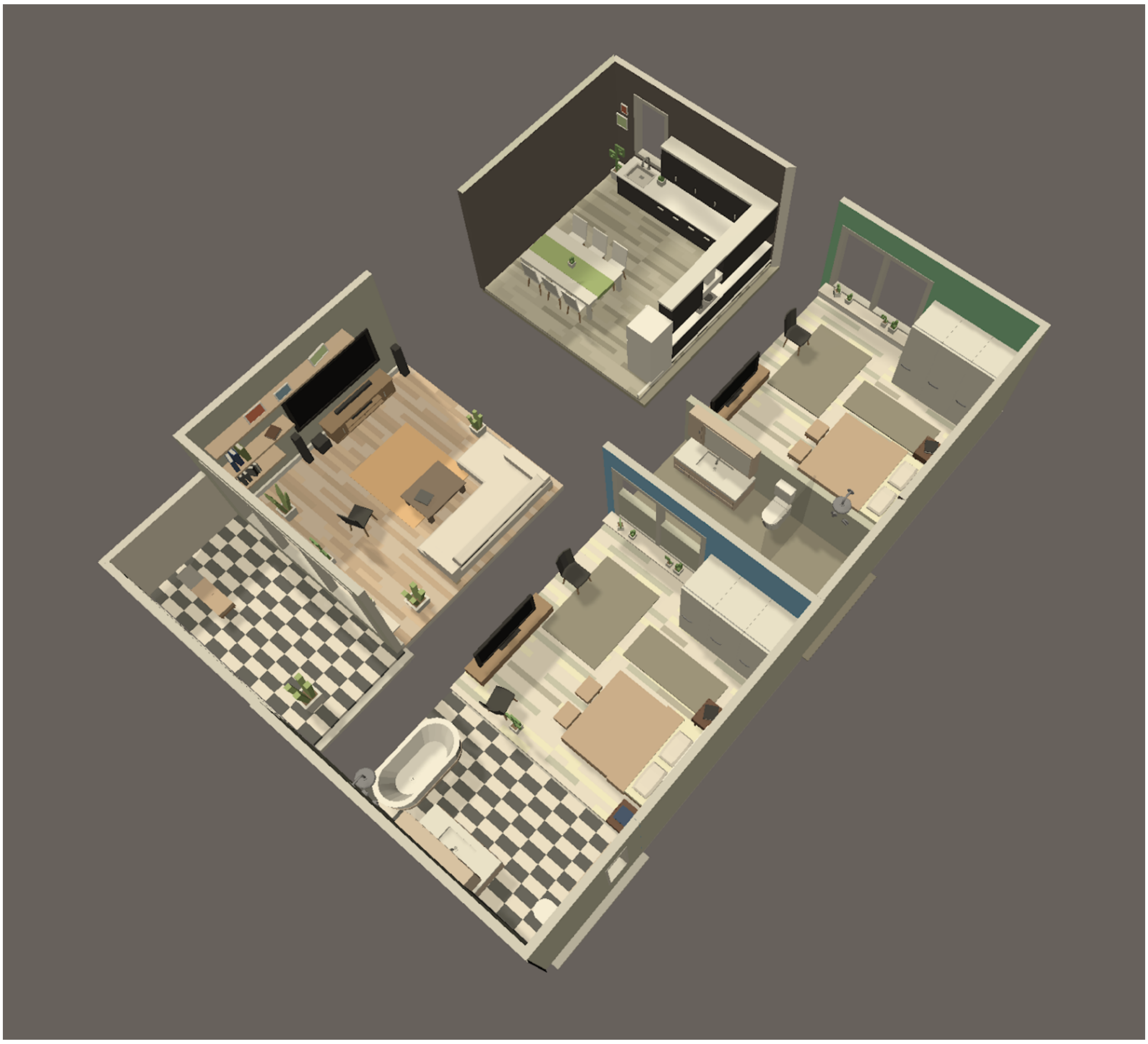


Figure 7-7 Screenshot of the digitally rendered apartment space.

After discussing the preferred interaction style, the researcher and the participants revisited the user scenario generated from workshop 2, and identified desired interaction style with more details using storyboarding.

7.2.3 Data collection and analysis

During each session of the three-part workshop, verbal discussions, and notes by both the participant and the researcher were audio-recorded and documented in the online space. Each participant also generated sketches based on the discussions, including the initial sketches of their ideal robot and scenario sketches. Drawing has emerged as an efficient and ethical research strategy to involve participants because of drawing's playful and co-constructive nature (Literat, 2013). In this study, drawing together was used for two reasons. First, the sketch looking nature of the drawings ensured the participants could express their thoughts using rough drawings. Second, drawing with a 'pencil' implies a work in progress, thus inviting both participants and the researcher to make changes during the process. In combination with storyboarding, drawing together was used to facilitate the exchange between the participants and the researcher, in turn, to gain deeper insights from the participants.

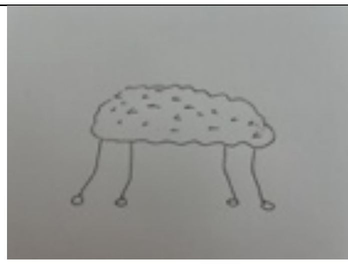
In this study, co-design outcomes transformed from an initial concept sketch to detailed scenarios, along with other verbal discussions and visual materials. Transcribed audio recordings were placed alongside the discussion notes and sketches generated during the workshop for analysis. To tackle all these materials, and capture the transformation through the three-part workshop, I borrowed ideas from the GLID method to support the analysis of the co-design data, including discussion transcripts and sketches (Mechelen et al., 2017). The method involved four stages: (1) grounding the analysis, (2) listing design features, (3) interpreting orientation and organisation, and (4) distilling discourse and values. The aim is to identify "deeper levels of knowledge" that reveal participants' "tacit and latent needs", otherwise not easily expressed verbally (p.117).

This study also followed an interpretive stance instead of a descriptive one to approach the data generated by participants. The descriptive stance seeks design inspiration, while the interpretive stance tries to deduce knowledge from co-design outcomes. A descriptive stance is also favoured in the latter stage of design, whereas an interpretive stance searches for knowledge and values embedded in co-design outcomes (Mechelen et al., 2017). Similarly, this study aimed to move beyond the robot concepts and the features generated in the co-design process to identify the rationales and values, implicit in the generated discussions and scenarios, underlining how retired adults conceive of the form, function, and interaction aspects of human-robot interaction.

7.3 Workshop 1: Ideate: participants' initial robot concept sketches

This section shows the findings from the discussions on the relationship between form and function, along with participants' ideal robot sketches and a short description of the rationale behind each sketch. Each participant made choices between the wheelchair bed and the robot bear and explained their choices.

The table below (Table 6) shows the participants' choices in Discussion 1, gender, and their initial robot concept sketches. Please see appendix 4.3 for participants' initial sketches with a short description.

Choice: Wheelchair-bed robot			
Participant	1	7d	9d
Gender	F	M	F
Initial sketch			

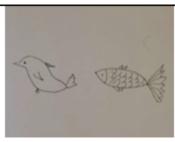
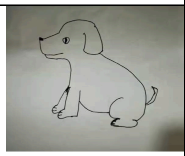
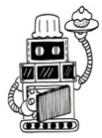
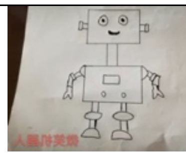
Choice: Robot-bear					
Participant	2	8d	13	14d	16
Gender	F	M	M	F	M
Initial Sketch					

Table 6 An overview of participants and their initial robot concept sketches, grouped by the choice of mobility assistive robot in Discussion 1.

All participants recognised the social status of the robot-bear. The recognition of certain characteristics is not enough to explain their decision, but depends on how they make sense of familiarity and social status with assigned functions. Three participants chose the wheelchair-bed robot for mobility assistance. They expressed concerns over control (P1), reliability (P7d, P9d), and familiarity (P7d). Five participants chose robot-bear because of its warm and approachable zoomorphic features (P2, P14d, P16), perceived usefulness (P8d, P13), and social appropriateness (P13, P16).

7.3.1 The familiarity of form and its meaning for individuals

Familiarity played a role in participants' initial assumptions about a robot's functional features, yet, participants' explanations of their chosen robots for mobility assistance suggests that individuals perceive familiarity differently. For some participants (P7, P9d), the familiarity came from familiar forms found in the home environment that align with known functions; therefore, the participants can predict the functional features of a robot based on its form. In other words, participants did not necessarily prefer familiar forms just because they were found in homes, but rather because of a familiar connection between the form and the type of functionality. Two out of three participants chose the wheelchair-bed because it required little cognitive effort to align the form and its function. All participants were familiar with a bed and a wheelchair, and confident to predict the tasks that the wheelchair-bed could complete.

> If you say the robot bear is an animal… it's not. It's so cold, it's only the form, like a big toy. I like when a bed is a bed, and a chair is a chair. (P9d 2020)

While familiarity relates to conventions and could reduce the cognitive effort to understand a new robotic product, some participants expressed appreciation of novelty.

> Everyone has seen a bed and a wheelchair, this is just something that combined those two. I want the bear, it's something new. (P16 2020)

The other type of novel robot form appreciated by participants came from reappropriating familiar forms found in real life and applied to the idea of a robot. For example, participant #1 found plants to be a familiar element at home, and participant #2 wanted a bird-like robot which could be used as a decorative element when not being used at home.

Participant #9d kept a dog for over ten years before it passed away. The participant likes the tactile touch of petting an animal; however, she finds fluffy hair unsuitable for robots and dislikes soft toys. Instead, the participant proposes a robot that resembles the form of a footstool that is soft. After a few iterations, the participant changed her idea to an alpaca robot with a fluffy exterior. She prefers the tactile touch that resembles the animal's fur.

> Alpaca would be wonderful. I don't want a dog…alpacas have long necks, and a robot would benefit from having a long neck, so it can reach higher places (P9d 2020).

Previous studies reported contradictory outcomes about older adults' preference for robots' resemblance to familiar forms. Bradwell et al. (2019) found that older adults preferred soft and realistic animatronic pets with fur; the roboticists favoured unfamiliar and realistic designs. The participants found unfamiliar animatronics infantilising.

7.3.2 Perception of social status and social burden from robot form

All participants recognised the zoomorphic features of the bear robot and considered it more sociable and intimate than the robotic wheelchair-bed. The attribution of social status allowed it to take on tasks that involved social interactions and caring for a person. While some participants (P7d, P14d) perceived the mobility assistance as a form of caring, and naturally expanded its functions, other participant (P9d, P13) perceived the same social status as a burden.

Three participants who chose the robotic wheelchair-bed revealed three different types of motivation. Participant #8d focused on the usability and reliability of two probes in a single task of carrying over a person from bed to wheelchair.

Participant #9d (female, dog owner) explained the psychological burden she worried about for sitting on a robotic bear because the participant did not associate sitting with a zoomorphic robot.

> I feel pressured, not so used to it. I lay on my bed, and sit on my chair. You should sit on a chair, you don't sit on a bear. (P9d 2020)

Correlating this comment with what participant #9d mentioned in Study 2 (sec 5.4.2), the zoomorphic characteristics of robot-bear. In previous interview, she considered the benefit of having a robot that provides consistent and personalised care. The lack of social bonding with the robot would make older adults feel more comfortable eliciting help. However, in this study, she expressed her discomfort of sitting on a bear, as she also perceives robot-bear's social status as a burden.

Five participants (P2, P8d, P13, P14d, P16) out of eight preferred the robot-bear to assist with mobility needs. All participants perceived the robot-bear as a social agent and considered that cartoon-like facial features were more friendly and approachable. In contrast, the robotic wheelchair-bed was perceived as an advanced piece of furniture. Three participants who preferred the robotic wheelchair-bed included two dog owners (P9d and P7d) and one non-dog owner (P1). Dog owners chose the bed because of the conventional use of bed and wheelchair. The non-dog owner assumed the robotic wheelchair-bed was less autonomous than the bear robot. Participant #1 was worried she might not fully control the robotic bear, which might threaten her self-esteem.

7.4 Workshop 2: Adding functional features and appropriate interaction styles

This section details the findings from the discussions about function and preferred interaction styles. Six out of eight participants expected the robot to have multiple functional features (Table 7), arranged from high to low priority. In general, cooperative interaction was assigned to productive tasks and implied usefulness. Playful interaction was associated with providing social interaction or cognitive stimulations. Participants' preference of human-led or robot-led depends on specific scenarios.

P#	Gender	Functions (arranged from high to low priority)
1	f	find and fetch / reminders / verbal conversation (cognitive assistance) / health-related tips / entertainment
2	f	verbal conversation / reminders / assist dancing classes / health monitoring / find and fetch
7d	m	safety monitoring / mobility assistance
8d	m	interactive training / game (fetch)
9d	f	cooking / health monitoring / news and music / answering doorbell / cooking / delivering tea
13	m	cooking / cleaning / health monitoring / reminders / news broadcast / entertainment
14d	f	verbal conversation / answer doorbell / play with dogs / cleaning
16	m	mobility assistance / delivery / reminders / health monitoring

Table 7 Participants' desired functional features of their ideal robot concepts

Two participants resisted adding a diverse range of functions to their robot concepts. Instead, participant #8d had a low interest in healthcare monitoring or verbal communication. He was fully satisfied if he could train the robot like a natural dog and play games with it. Similarly, participant #7d preferred to use wearable or smaller mobile devices for health monitoring, news broadcasting, and entertainment.

7.4.1 Niche-finding in contextualised scenarios

The co-design process provides a space for the researcher and the participants to share knowledge which can help bridge the gap between functional features and technical solutions. Some functional features requested by retired adults are not met by technological solutions, for example, cooking meals and doing laundry (P13). Participants provide insights into how technical solutions could be integrated to fulfil their needs in contextualised scenarios.

Participant #7 was taking care of his father when the interview was conducted. Based on the participant's informal caretaker experience, he strongly desired a walkable robot operating during the night. The robot would fulfil a real need that benefits the primary user (participant's father), the participant, and the live-in caretaker. The participant had limited expectations and trust in robots' capability and reliability; therefore, he proposed a robot with specific functions and operation time. The robot is expected to sense his father's movement, who gets up 3 to 4 times throughout the night. The participant imagined an android robot which could switch on the light and accompany his father to the toilet to ensure safety, and alert him if any accidental falls occurred (figure7-8).

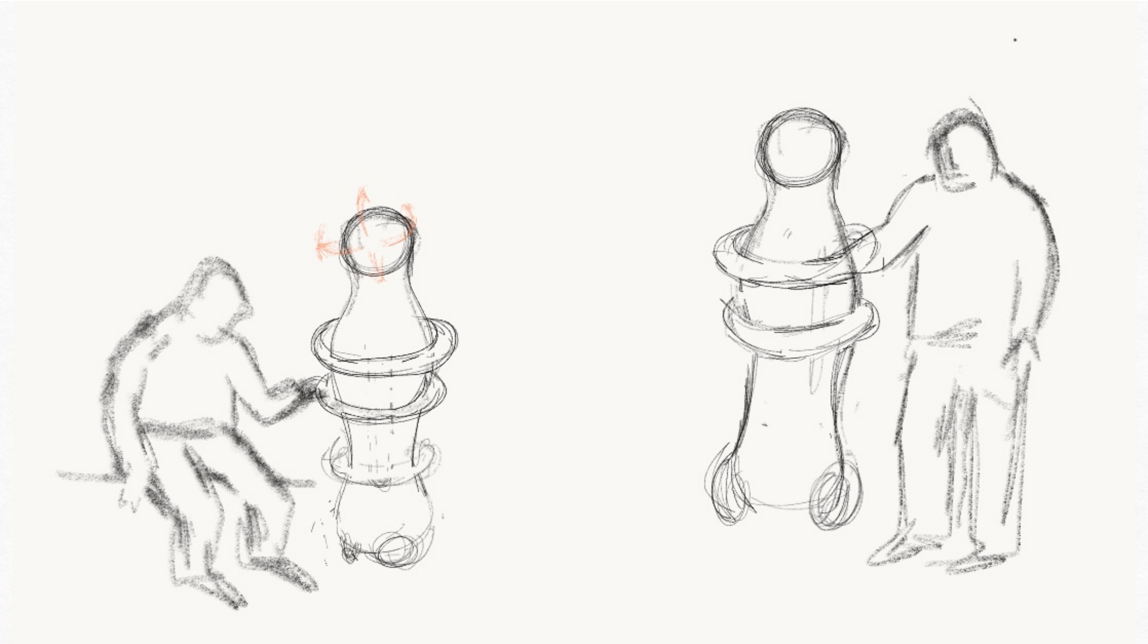


Figure 7-8 Scenarios generated with participant #7d.

Compared to a smart home set-up where lights react to his father's movement and play messages that caution his father through speakers on the wall, the participant preferred a social/assistive robot to carry out tasks in this scenario. Given another possible option of a wearable robotic skeleton, the participant found a robot would be much preferred, considering it would be time-consuming for his father to put on a wearable robotic device all by himself, and such a solution would lack the sense of support from another social actor:

> A robot could guide him, and remind him to pay attention to his footwork, I would be more at ease as well. (P7 2020)

The final design of the robot resembled a duckpin in a bowling game, with two rings for easy grips at different heights (figure 7-8). An illuminating light was on the top, acting as the head of the robot, able to turn in four directions. The robot can navigate the space on its wheels powered by a battery and accommodate the human's walking speed by switching to a human-led mode that allows users to push forward themselves.

7.4.2 Customisable interaction style according to functions

All participants perceived cooperative interaction with the robots positively; however, this depended on the context. Cooperative interaction was associated with all tasks that require social interaction to provide assistive support. All participants approved the usefulness of the functional feature of reminders for taking medicines. The participants preferred the robot to remind them in a friendly and supportive manner.

However, when presented with the case of not completing the activity or task after a reminder, participants had different preferences of how they expected the robot to behave. Most participants expected the robot to ask them about the completion, remind them again in the future, or remind them no more than three times until a certain time point. One participant (P3) preferred the robots to be more authoritative and hoped the robot would supervise him in taking drugs on schedule and making suggestions on his diet.

Participant#1 hoped the robot could interact with her according to highly customisable settings, which executed the tasks differently depending on context. For example, when the robot was set to 'owner is busy', then it would minimise notifications and pause all entertainment suggestions. This shares similarity with the idea of personalisation during use that was discussed in Study 3. In other words, the robot was expected to utilise contextual information from the user and the environment.

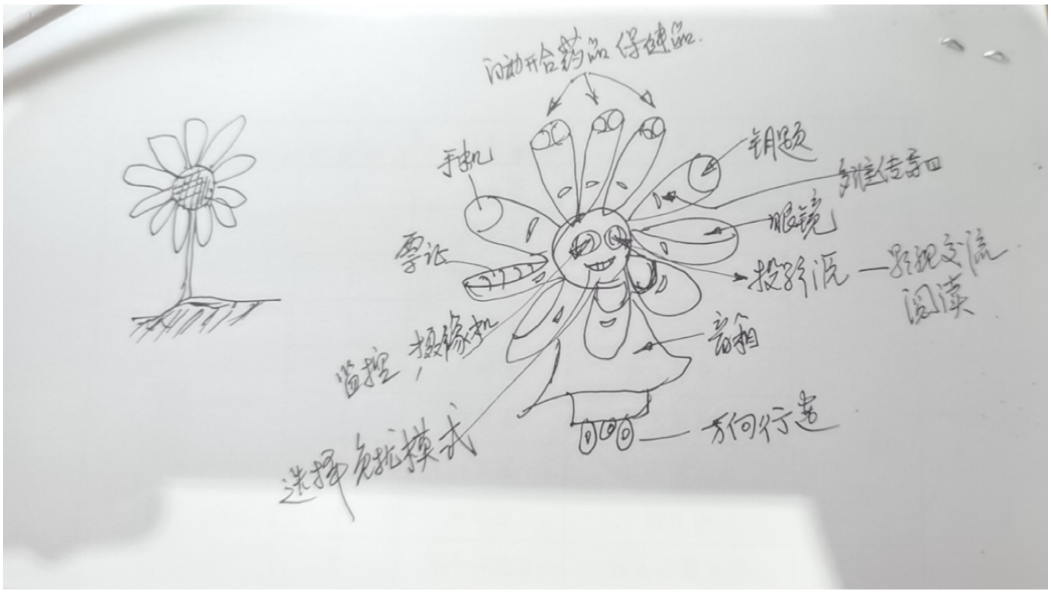


Figure 7-9. Functions sketch generated with participant #1.

In the sketch (figure 7-9), participant #1 indicated that the smiling teeth on the flower robot could be a physical interface for her to switch between saved settings. On the other hand, the smiling teeth would double as a display to inform the participant about the robot's protocol; hence, the participant could adjust her behaviours in response to the robot.

7.5 Workshop 3: Scenario-based storyboard

Most participants expressed having more free time after retirement. They started spending more time with grandchildren, reconnecting with friends, and making new friends. Following this increase in social life, they imagined the robot to fit into their social gatherings directly or indirectly. Dog owners expected the robot to interact with dogs at home as well. Five out of eight participants imagined their robotic concept in scenarios with other social actors, such as family members, friends, caregivers, and pets.

7.5.1 Integrating the robot into social scenarios

Participant #1 generated one scenario where the robot would stay close to her while she had conversations with friends. The unintrusive movements of the robotic petals could indicate its presence in the conversation. The robot would be ready to respond to her questions and take notes for her upon request, search for information and project videos
if asked, and remember who she had conversations with by learning her friends' faces.
She designed her sunflower robot to participate in tea parties, take notes, help her to remember good discussions, and occasionally interrupt the conversations or tell jokes as if the robot was her "secretary" (figure 7-10).

Figure 7-10 Scenario sketches generated with the participant #1.

Participant #8 was experienced with dog training and focused on the pleasure of training a dog. The participant expected to compete with his friends, who might also have robotic dogs.

> Dog fights are cruel for dogs, but if I could train a robotic dog and compete with my friends, we could meet regularly, and see who trains their (robotic) dogs better. (P8 2020)

In this scenario, the robot becomes part of a hobby that helps the participant reminisce about his experience when he was young. In addition, the hobby mediates social interactions with other humans and communities with different age groups. While the robot does not fulfil standard utilitarian functions, it provides a vehicle for the participant to engage in a potential community, which benefits positive ageing.

Participant #14 hoped the robot could play with her pet dog at home when she was away; however, she would prefer the robot to ask for her permission to play with the dog rather than engage with her pet dog proactively when she is home.

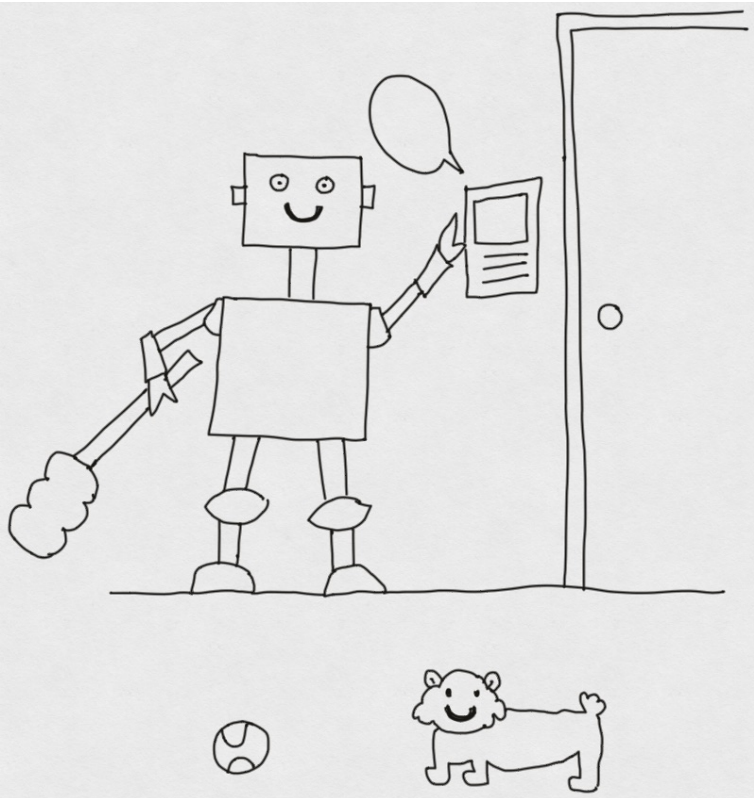


Figure 7-11 Scenario sketch generated with participant #14d.

7.5.2 Interactional style depends on the social context

Three out of eight participants preferred the zoomorphic robot over the furniture robot, including one dog owner and two non-dog owners. Five participants chose the furniture robot because of its dog-like behaviour. All participants still preferred to see a consistency between the form and the interaction style. It is easier for participants to accept a robot with zoomorphic features to perform a range of social behaviours.

On the other hand, participants' insights shed light on a potential nuanced balance between the expected form and how it interacts with users that should be addressed. The participants welcomed zoophoric robots to engage in social interactions and activities related to care work. They considered the robot's social interaction competence a determining factor in the overall experience, including the aesthetic elements critical to providing a positive experience and the functions required by the participants.

All participants expressed the need for a reminder function, and their proposed user contexts cover a range of activities. For example, reminding family members to join the dinner, reminding the user to take medicine, or reminding users of important dates (i.e. grandchild's birthday). A functional feature alone does not determine whether an interaction is social or utilitarian. Participants' perception of tasks would influence their expectation of a robot's function. For example, participant #9d considers being called to dinner is very warm, and prefers a dog-like robot in this scenario (figure 7-12). It is important to understand how a participant perceives a task or activity a priori, and understand the robot's functional feature as part of the activity.

> Asking me to go to dinner is very warm...it would feel strange to have a furniture robot tell me. However, I also want it to behave more dog-like too. If I have to pick one... I'd go with the dog one. (P9d 2020)

Figure 7-12 Scenario sketch generated with participant #9.

Participant #2 emphasised the need for the robot to be useful when both stationary and mobile. As seen in figure 7-20, the bird robot can be used as a phone stand and a projector that plays videos about dance routines. The participant goes to the community centre two times a week to dance with other retired women. However, she needs more time to practice, and it is sometimes hard to follow the dance routines without practising. The participant proposed a bird robot which could be resting in a nest on the coffee table in the living room when it is not occupied as a decorative object. The bird's small size allows the participant to carry it outside the home. It could be used as a recording device that could easily change angles and film the dance routines for the participant during class. The participant hoped the robot would be able to fly around the home and stand on furniture. The participant reflected on digital devices she abandoned and designed the robot that serves an aesthetic function as decoration when it is not in operation.

> Robots take so much space, and if you don't use it as often then it is just taking space...if a robot that's small and can fly around the home, it won't take much space. (P2 2020)

Figure 7-13 Scenarios generated with the participant#2.

Participant #8d, with experience training hunting dogs in the past focused on the robot's interactions. He desired a robotic dog that would spark a joy similar to training hunting dogs. This kind of interaction does not serve to complete any utilitarian tasks; instead, the value is in the aesthetic quality of the interaction itself.

7.6 Discussion

7.6.1 Gender-based difference

Gender played a role in material preference and functional features. All female participants spoke about the maintenance (cleaning) aspect of the maintenance of the robot, which influenced their preference for the robot's material. While both fabric and silicon are soft, female participants preferred silicon because it is easier to maintain and clean. Individual needs and previous experience in eldercare determined the priority of functions.

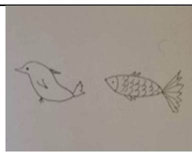
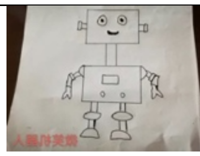
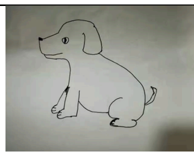
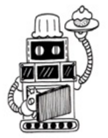
Female participants				
Participant	1	2	9d	14d
Choice	Chair-bed robot	Robot bear	Chair-bed robot	Robot bear
Initial sketch				
Male participants				
Participant	7d	8d	13	16
Choice	Chair-bed robot	Robot bear	Robot bear	Robot bear
Initial sketch				

Table 8 An overview of participants' initial sketches grouped by their genders.

In a study that involved three embodiment workshops, Caleb-Solly et al. (2014) found a significant difference between female and male participants’ primary concerns. The researchers reported female participants’ primary concern was social companionship; male participants focused on functionality and cost. This study suggests a similar gender-based difference. Additional evidence to support the difference in primary concerns. Male participants explained their choices of preferred form based on their assumed functionality features. Male participants’ sketches show a preference for humanoid form because they believed a humanoid is capable of “cleaning” (P16), “cooking like a maid” (P13), or “standing in like a night nurse” (P7d). Except for participant #8d, with extensive experience in dog training, all male participants conceptualised their preference of form and interaction style to support utilitarian functions. The emphasis on cleaning tasks and help in the kitchen is consistent with the idea that older adults accept a robot as a "technological compensatory method" (Beer et al., 2012). However, this acceptance factor may be more prominent in male participants.

On the other hand, the female participants focused on the robot's size, material, and appearance. The robot concepts generated by the female participants showed a similar emphasis on "social companionship" (Caleb-Solly et al., 2014). The female participants developed diverse robot forms, taking inspiration from familiar, yet novel forms, like sunflower (P1), bird (P2), and zoomorphic stool (P9d). These forms resulted from their consideration of integrating the robots into the home environment. Furthermore, Caleb-Solly et al. (2014) found this desire to fit the robots into the domestic environment among the male participants, instead of female participants in this study. One exception is participant #14d's robot sketch; however, the "smile" (participant annotated on her sketch) is coherent with the findings.

7.6.2 Limited influence of dog-owning and training experience

There is no significant difference in dog owners' preference for robots' form. However, dog training experience played a role in how retired adults considered the functions of social robots. The dog-owning participants without training focused on the robot's functional features and form, but less attention to how they could interact with the robot. They preferred the social/assistive robots with utilitarian functions. On the other hand, they highly valued the social status of their dogs. They proposed no functions that would replace their companions. Instead, robots were used to take care of the dog (P14d), or help them to remember their previous dogs (P8d, P9d).

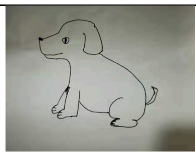
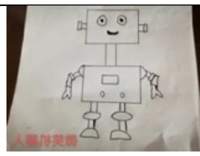
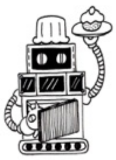
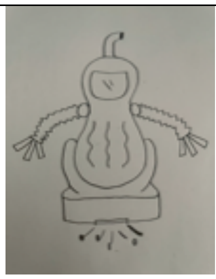
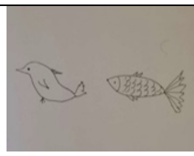
Dog Owners				
Participant	7d (male)	8d (male)	9d (female)	14d (female)
Choice	Chair-bed robot	Robot-bear	Robot-bear	Robot-bear
Initial sketch				
Non-dog owners				
Participants	13 (male)	16 (male)	1 (female)	2 (female)
Choice	Robot bear	Robot bear	Chair-bed robot	Robot-bear
Initial sketch				

Table 9 An overview of dog-owner and non-dog owner participants' choices of robot in Discussion 1, and their initial robot concept sketches

7.6.3 The social nature of social/assistive robots and the need for complex interaction protocols

Individuals make meanings of different tasks carried out by robots, especially within the context of the home, and the meaning of these tasks is often beyond merely utilitarian purposes. Duetsch et al. (2019) recommended integrating the robotic device's social features as a secondary function, but not a leading function. This study shows the social nature embedded in all functions. The social nature emerges from the direct interaction between the user and their robots; it also appears in interactions with other social actors.

While an extended period of interaction with robots could help align users' expectations with the actual functionality of robots, it is worth noticing how participants made sense of the interaction in relation to functions and form based on their gender. The interaction should be personalised to what the users consider appropriate. The scenarios are defined by functional features, how functional features take form, and the alignment of the robot's interaction styles and participants' conception of the activity. Six out of eight participants imagined scenarios that involved other human social actors and pet animals, pointing to the necessity of building a robot's interaction protocol.

7.6.4 Reflection and limitation

The order of the three workshops may have influenced the development of the sketches and storyboard. In a similar study that visualised robot concepts with participants, Lee et al. (2017) engaged three older adult participants in a focus-group workshop, which led to a focus on developing robot sketches that provide companionship. Instead of starting with functions that solve challenges the participants face, this study remained open for the participants to select their desired robots' functions. This encouraged the participants to contextualise scenarios that are meaningful or useful to them.

This study worked with a specific group of educated, financially stable, and university campus-based retired adults; therefore, their robot concepts cannot be generalised to all older adults. However, engaging participants using sketching and storyboarding can be applied to a larger sample of participants. The participants in this study had no immediate care needs, which impacted how they perceived their needs and attitudes toward the robot. Though the participants had no immediate health-related needs themselves, they have varied experiences of caring for the older generation. This strongly influenced how individuals expected their robot concepts to assist in caring for older people. The materials collected from the study show two responses from the participants. First, participants are more aware of the emotional labour in eldercare, and the division of labour among different members who are involved, which results in specific expectations of a robot. Second, participants were more positive about integrating robots as part of an activity that promotes active ageing.

7.7 Summary

This study shows no significant difference between how dog owners and non-dog owners. However, gender played a critical role in how participants unified the form, function, and interaction aspects of their ideal robots. From the initial sketch to placing the robot concepts in contextualised scenarios with other social actors, the participants showed the importance of social features and the social nature of robotic agents. It is suggested that social features should always take into consideration with the primary functional features.

Two recommendations are identified for future co-design workshops. First, maximise the use of contextualised scenarios. Participants who imagined scenarios of group interactions involving multiple humans, robots or pets constructed more detailed mental models of how they might interact with a robot at home. Participants could recall and reflect on more contextual information under specific conditions.

Second, make use of the gender-based difference. Male participants tend to prioritise functional features as the basis for conceptualising interaction style and form; female participants tend to use the form as their basis to conceptualise functional features and interaction styles. Building on this tendency, the procedure of similar co-design workshops could conduct separate sessions for male and female participants, to lower the barrier of ideating their robot concepts.

8 Conclusion

This chapter summarises the findings of the four studies conducted for this research. It also details my contributions to the field of Interaction Design Research and Human-Robot Interaction. Finally, the limitations of the research are considered and suggests paths for future research.

This thesis has addressed the following research questions:

1. How could (in what way) the human-dog interaction model informs the design of social robots to meet the needs of older adults?
2. What role would aesthetic, functional and behavioural aspects of the human-dog interaction play in older adults' interaction with social robots?

In the next sections, the findings and conclusions will be detailed following the research journey (figure 8-1).

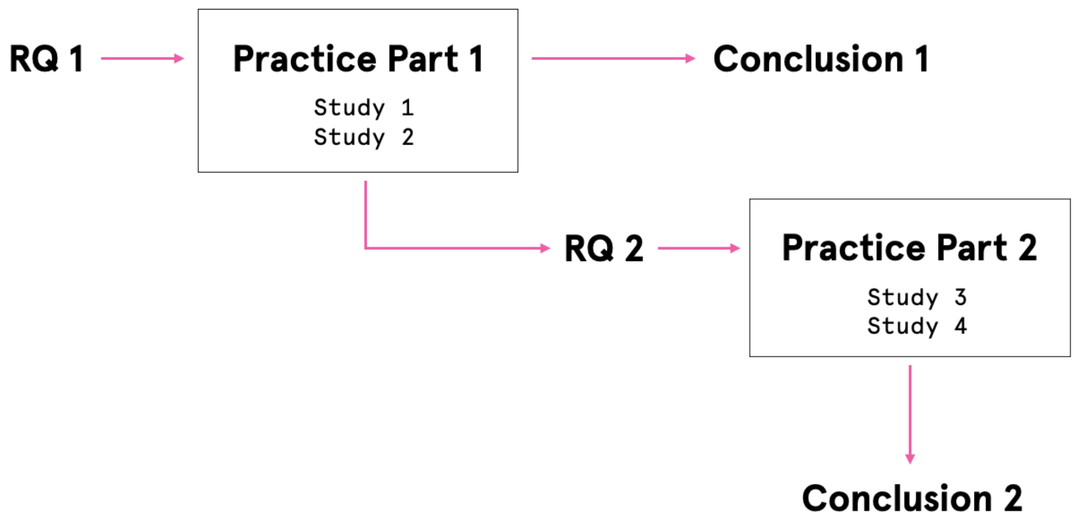


Figure 8-1 The order of findings and conclusions produced during this research.

8.1 Contribution

8.1.1 The analytical and generative use of metaphor

This thesis started with identifying relevant works, from different disciplines, that use human-dog interaction as a model to speculate on the human-robot interaction. According to Lakoff (1993: 211), a metaphor involves carrying over the frame from a source domain to a target domain, to provide a new perspective. When reviewing conclusions from literature reviews that are complementary or contradictive, I used the robot-as-dog metaphor to analyse the relevance to human-robot interaction.

At a lower level of abstraction, the robot-as-dog metaphor implies using dogs as a source domain in a specific and highly selective way. This might include reverse engineering certain dog behaviours, with which to endow dogs, by using biomimicking. For example, a robotic dog might learn how to walk and run like a real dog, also known as robotic imitation (Peng et al. 2020). This kind of contribution to the design of robots is likely to be made by robotic engineers or experts in artificial intelligence, and validated by an instance of a working robot prototype. Similarly, cognitive ethologists might contribute in this way. This includes examples of work done under the lead of Miklósi, in which the way a robot executes a task is carried over from behaviours observed in dogs completing the same task. At this level, analogical reasoning is the core principle.

At a higher level of abstraction, the reasoning behind the robot-as-dog metaphor involves relational structures, also known as metaphorical reasoning (Choi and Kim 2017). In this thesis, this is exemplified by Miklósi's proposal of ethorobotics, whereby the theoretical grounding of dogs' evolution is borrowed to propose a theory for robots' evolution, and how this could survive within human society.

The contribution of design research is situated in the middle between a low and high level of abstraction. It is at this level that design practice and its iterative process of reflection and creation adopts methods like metaphor and co-design to achieve new understandings and produce new knowledge. Going beyond the analytical use of metaphor in the first part of this thesis' practice, the second part of the thesis' practice identified the personalisation of robots as a training metaphor and designers as trainers, thereby demonstrating a generative use of metaphor in co-design practice.

8.1.2 A reflective practice of co-design for HRI

This research shows how the reflective practice during the process of co-design human-robot interactions provides a complementary perspective to technology-centred approaches. It is important to engage different disciplines in human-robot interaction research, and articulate the role and implications of design research methods in a multidisciplinary team. The co-design approach which involves robotic engineering and computer science in the process provides an example of how articulating details of metaphor, in this research, personalisation as training, facilitates the communication among stakeholders to bridge the gap between what is the right thing to make and how to make the right thing. The reflective practice of co-design for human-robot interaction involves both reflection-in-action and reflection-on-action. In reflection-in-action, designers are mindful of the different interpretations of the robot-as-dog metaphor and its implications for the co-design process. The resulting tensions could be addressed by co-design teams through discussions of whether personalisation should be seen as customisation or training. In turn, end-users could be involved as participants in the co-design process, enabling them to improvise during the deployment of probes as they explore possible adaptations of robots' form, function and interaction aspects in context. Reflection-on-action is important during the entire co-design journey, to analyse the turning points in the co-design process and the usefulness of discussing the robot-as-dog metaphor in collaboration.

The reflective co-design practice also allows participants and designers to learn from each other and understand the rationales behind their sensemaking of the relation among the form, function, and interaction aspects of robot concepts. Understanding the interrelation among these key aspects can support the design and construction of robots situated in participants' lives and respond to their diverse practical and socio-cultural needs.

8.2 Reflection and Limitation

This research is based on a small sample size that draws from a specific socio-economic group. However, generalizability was not of primary concern in this research; instead, the primary concern was engaging closely and over a period of time with relevant participants in co-design practice that could facilitate an in-depth exploration of the research questions. Healthy retired adults were recruited from the same community to explore the potential space for social robots built for older adults.

Due to the travel restrictions brought by Covid-19, study 4 had to be conducted online, with participants providing their own smartphones to access the online collaboration space. The influence on research findings of using digital tools in an online collaboration space to co-create sketches was not evaluated.

8.3 Future Works

8.3.1 Studies on multidisciplinary collaboration

More importantly, more studies should be conducted to explore how design could be positioned in an interdisciplinary field like HRI (at the crossroad of machine learning and design). Reflective practice in co-design could contribute to establishing "research *through* design" methods in the field of human-robot interaction. Communication and the languaging of design are often overlooked in the research process. Critical engagement of metaphors used in the co-design process could help to facilitate the communication between team members from different disciplines. Moreover, articulating the underlying rationales and discussing the implications of emphasising particular disciplines could contextualise insights provided by participants as co-designers.

8.3.2 Experimental studies using Unity

This research reveals the relevance of pairing and training in human-dog interaction to build personalised social robots. The first version of Unity Machine Learning Agents Toolkits was released one year after I started my research. This revolutionary release enables Unity to be used as a platform for training agents using machine learning techniques. Real-time training in virtual space using machine learning techniques would save time and resources. A need has been identified for further research on how retired adults could carry out modifications on the form, function, and interaction on a collaborative digital platform, and interact with personalised robots in sketched scenarios. This thesis contributes to the field by offering a framework for highlighting the role and implications of adopting metaphor and co-design as methods for human-robot interaction research.

8.3.3 Longitudinal studies

This research could benefit from longitudinal studies that continue the iterative process with retired adult participants, roboticists, and other disciplines' representatives to conduct reflective co-design workshops. Longitudinal studies could provide further insights into the richness of users' contexts and reveal factors that contribute to participants' sense-making of robot conceptions in terms of form, functional features, and interaction styles in a diverse range of scenarios. Moreover, conduct more co-design workshops with researchers in fields such as modular self-configurable robots and interactive reinforcement learning to further evaluate the usefulness of personalisation-as-training in developing personalised robots.

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Appendices

Please see the Practice Documentation submitted in digital format, including materials and relevant documents in each study. There are in total of four folders correspond to the four studies conducted in this research.

1 Appendix 1 Materials used Study 1 (Chapter 4)

1.1 Semi-structured interview questions for dog trainers

The following guiding questions were asked before I conducted my observations with the dog trainers in each human-dog dyads.

1. Would you please tell me about what you do?
2. What do you think robots can learn from the dogs?
3. What advantages a robot might have over a dog?
4. Do dogs "train" humans to do things for them?

1.2 Selected videos of dog training sessions

Please see videos inside the folder Study 1_Chapter 4

- Study1_Pet_dog_training.mov
- Study1_Guide_dog_training.mov
- Study1_Police_dog_training.mov

2 Appendix 2 Materials used in Study 2 (chapter 5)

2.1 Consent form and research information sheet

Please see documents in folder Study2_Chapter5

2.2 Extracted samples of interview transcripts

2.2.1 Interview transcript with P2

R Hello, thank you for coming. How was your trip finding here?

P It's no problem. I live on the block, on campus. It's easy for me to get here. It's only about ten minutes' walk for me. I live right over there, it's no trouble. Weather is good too.

R It is indeed nice today. Do you come here often?

P I guess so? I have class tomorrow here, this semester's dance class. They just hired some student from the art department at the university as the teacher for us. They don't charge much. It's almost free, so that's pretty good.

R That's great. Is dancing something you picked up after retirement or?

P Yes, hmm…now I have time, you see? Last semester, we did more posture work. This semester we are doing ethnic dance, the songs they picked are very popular right now. Do you know "da yu"?

R Mhm. The theme song for that animation, right?

P Yes, yes, you know. we even bought fans online. We are doing a final performance at the end of the semester. It will take quite some practice. But it's good.

R What else do you do?

P It's just the dance classes for now. It's twice a week, and I practice at least once a week with my friends, otherwise, I can't keep up. You'd think I have more energy than those who are older than me, but these sisters got so much energy. Some of them are even in the choir, or yoga classes. I tried yoga as well, last year, but some poses are too challenging. Dance is easier, and it's good for my posture.

R How do you find retirement in general?

P I retired as soon as I can. There wasn't much to do for me at work, makes not much difference. I'm pretty much in this state a few years before the official retirement. I liked my colleagues, but I didn't go that often in the end… it's ok. I have all the time to myself. I like the slow pace. I only find too many things to do, to be honest, something here, something there, then, woosh, all day is gone.

R Sounds like you have a busy schedule. Tell me more about it?

P Not busy, not really. It's just the chores around the house… my husband still works, and he is very busy. I'm home alone most of the time, until late, and he works overtime.

R So you spend a lot of time by yourself? Or?

P Well, there's that dance class…otherwise, I don't like too many people, all bustling… I like spending time with my plants and do some cleaning around the home. I used to have a schedule, because I go on stock market every day, I need to go (online) while they are open. but it takes too much energy. Now I just relax. There's still a lot to do around the house, watering plants, pruning, cooking, cleaning.

R Sounds like you adjusted to retirement pretty well. Do you have any recent or future plans?

P Hmmm…how far do you mean by future? 10? 20? I haven't given much thought yet… just stay healthy? I can only be responsible to myself, so I take these classes to stay active.

R What about pets? Have you ever had one? Would you consider?

P Oh no. I never did. I don't know, they are cute, but they aren't for me. I'm more of a plant person. Everyone else love little animals, but I prefer plants. They are easier to take care of, and quiet. Dogs…you need to take care of them. I'm busy taking care of myself, plants are better.

R I see, thank you for telling me about your retirement life. Now, I'd like to invite you to have a look at 4 robots. I will play a short video, and ask about your opinions, is that ok?

P ok.

(play video)

R	Do you have a Roomba at home? What do you think of it?

P	Mine is gathering dust at home, I still use it… but it requires so much work…I have little things around on the floor, and I need to move all the things off the floor for it to work. If I'm not home that's ok, but if I am, the noise is …sometimes annoying. But then you kind of need to be there, to clear the way for it you know, otherwise it doesn't cover all the areas. It's not that smart, maybe the new model is better.

(play video)

R	What do you think of AIBO?

P	Actually, I think the robotic dog is not bad. Because, first of all, dogs can't live forever, and two of my friends, their dogs left them recently, and they cried so hard. Dogs can live for over a decade, right? And this robotic one it can entertain you, and also play on its own. This is good, maybe I could even interact with it.

(play video)

R	What about ElliQ?

P	If it moves maybe, it is still, so comparing to AIBO, it doesn't tick for me. Can it chat with you? Speaking is important. Many older adults are lonely, and more prone to develop dementia, because no one to speak to. Though there are wearable ones to help with hearing, but much noises come into it as well.

It should be combined with the AIBO, AIBO doesn't speak, but speaking is important. So yeh, combine them, to make ElliQ more smart, like AIBO. Dogs are like a child of 3 or 4 years old, just can't speak. So some simple conversations would be fine.

R	So it's fine if it doesn't speak smoothly like you would converse with another person?

P	Hmmm, I doubt you can do that.

R	How do you find CareObot?

P	Actually, CareObot should be able to talk and recommend things just like ElliQ right?

R	It could speak, what do you think if it can speak verbally?

P Since it's so big, I expect to do many things. If it's just notifying people and deliver items to me, then I won't consider it. It runs around at home at night? So scary.

It's just too big, like you need it to operate during the night right? If you want it to monitor then you need to keep it on when it moves around, and it would detect strangers and guests that come in, and if you don't keep it on, it wouldn't know you fell. It's so creepy to have it in the dark, because it's tall, but it can reach higher shelves.

R Comparing these robots, which one you think has the best form?

P AIBO is most adorable, but maybe ElliQ is more useful? It has all the functions and seems easy to use. For older adults, if it's too complicated, it would be difficult. And it takes little space, you just place it on the desktop right? Reminders to take medicines and recommend entertainments for older adults are both good.

Because it (ElliQ) is placed on a fixed spot, it wouldn't know if you fell or not. If you place it in the living room and you fall in the bedroom, it wouldn't know.

R Which would be more useful to you?

P Hmmm, can it feed me? If I can't move? I don't think CareObot is useful much, it can only do so much in the video and it requires such a big space at home? Actually you should combine this with something that talks, then it would speak as well. Software doesn't take space, you can put it anywhere. It can also recommend songs, and walk towards you. Putting something some where, and when it's not occupied, it can chat with you. Something alike that can learn, like a helper.

R Would you trust any of these robots?

P Well, if it's soft, and precise with movements...hmm hard to imagine, but I want something to be able to deliver food and feed me. When it comes to robot, first is function, then you add the flexibility, then you have more functions, then it becomes a real intelligent robot (CareObot), then it can order songs for you (ElliQ), otherwise, Roomba is also intelligent.

R What do you think of privacy issues? Any concern?

Oh, trust, well, if it's a machine, it would have a back door and bugs, then it would be stolen by others, read your data or data of your home. But I'm not some famous person...just a regular person. haha.

And this one, looks like AIBO, and CareObot looks like a big air conditioner, it needs to be adjusted, doesn't look cute. For older adults, it need to look cuter and smaller. I for sure will use Roomba to clean the house for me when I'm old, then I will use something like a AIBO if it talks.

I don't like how CareObot looks, too heavy ... makes my head hurts... maybe only when I can't move... but you can't ignore how it looks, and then you need to take account of how much it costs. Like this would look cheaper (ElliQ) than CareObot.

Also, in the video, when you deliver water, someone else need to put it on there, don't think it helped that much. And it reaches over, I need to find where it's arm is. It should be able to complete the whole thing itself when I say I want some water, and then can also chat with you standing around... but it must be so expensive.

2.2.2 Interview transcript with P1

R Let's have a look at some robots designed for older adults_

P Would it (CareObot) able to help the person stand up again?

R No, but it would contact someone for you.

P Ok. If you fall, this could be useful.

I know there's an incident that an old couple, one is paralysed, and then one fall.. so they can't help each other. They set their air conditioner wrong, it was blowing hot air in the summer, and they passed...because they can't contact anyone, and one has dementia, and was relying on the other one, but other one fell. Only found them when neighbours start to smell things.

There were in total of three incidents I know like this. And someone else who jumped, and the police came. His family didn't even know, since he was ok even two days ago, then the kids went out to work, and he jumped. The grass is tall, so they thought he just went out and get lost. They didn't think of that. They didn't think he was suffering from depression, so the AIBO would be pretty good if one suffers from depression.

Now the smart speaker Xiaodu is pretty good. I tell it, find me a song, it replies what song? I can't find it but I have something similar. It can speak to you, and you can talk to it too. If you scold it, you are so dumb, it would say I am a little silly, or if your tone is bad, it would say it's not nice of you to talk to me like that.

You need some external stimulus, yes, like speaking is just that. Our ability to speak gets worse as we get older. Someone I know loves debating, some little things he would speak forever, but now his ears aren't acute, and he has no input anymore. He follows around his friends, like some other meek older person. So yeh, how to stimulate him to listen, and those wearables, aren't good either, it's easy to get infected when you wear them.

R That's understandable, let's have a look at ElliQ

P Yes, reminding older adults to take medicine is important, and high blood pressure, yes, these functions are good.

R Which one do you think that's most useful to you?

P Maybe CareObot is good for certain things, but ElliQ is more useful since it can remind older adults and recommend programs, so this is good.

AIBO seems more about emotion, and visual. You can hug it… it has some function, it is a function. But not as useful as ElliQ

And the functions can be further developed. Like you could video call with your kids right? If this can be moved onto CareObot, then it can monitor the person more closely. Like it can actively go and recognise, better yet, can help the person get up.

Now wireless is easy, you can also put cameras up in the rooms.

R You don't mind cameras being installed?

P When I would easily fall, I think so. As long as I can stay at home, since I'm not old to the point to go to nursing homes. Cameras are ok. This is more about information security.

R Which robot's form is more appealing?

P ElliQ would be in the cute category but not as cute as AIBO. Then functions. It need to have both, functions and emotional communications.

For example, if someone is resting on their bed, he can remain comfortable, then you need something combined. Like those with more functions can go warm up your food, or use the oven, since it's easier. Take food out of fridge, and put into microwave, get you some milk. Like a personal care taker, I think more functions need to be developed for those who are on beds.

R Which one do you trust the most?_

P I think ElliQ and Roomba are both ok, it's just how clean it is. And ElliQ rely on big data banks, it would work, unlike autonomous cars.

R Which one would be most useful for you?_

P I think when I'm healthy I would go out, but when you return home, no one is there, so something I can talk to would be most useful. It can tell me things I don't know from its data library. Songs I want to listen to..I think this would be very useful, and emotional communication. Could change it to be like a little kid, it might even compete with kids, haha.

R You would want it to look like a human child? Or doll?_

P Like how it thinks, can be set like a child. Even dogs, are like kids. That's why I said they can be combined. If I'm healthy, yes, the emotional communication would be great, but if I lie in the bed…yeh…maybe CareObot if it has more functions. Because other things you can realise it with internet of things, now 5G is on its way, thing will be easier. Therefore, it needs to be soft, needs to be flexible (CareObot). I hope this can be developed.

R Some said the more a robot can do for you, the less independent you become, what do you think?

P Yes Independence is important, that you are in control. This is a strong position, to be independent. Well, I think humans are in control of machines. And I think cybersecurity will be improved, otherwise, I wouldn't even use banks. First, it's a machine, then a person programs its functions. It's the difference of high level or low level…like if I push some buttons then I can set its settings to be how secure.

Now not many thieves since nothing are home, they are all on your card, and he can't know the passcode. And I don't worry that much about my data, maybe it's useful for others when it's collected together, if someone needs to analyse a group, and I'm part of that.

R Which one is useful for you

P The most immediate is ElliQ, since now not that many people…and I need to talk to people. Since I'm still healthy, ElliQ would be enough. To talk to me, let me know more knowledge, like how to do things. I think this is most desirable.

I wanted to enrol the spoke poetry class, but I can't enrol now and I speak less. I feel I need to express and use my organs!

CareObot is for the future when I can't move. I don't need it now.

2.2.3 Interview transcript with P14d

R How did you come to have dogs? What breed? How long have you had your dog?_

P I used to fear dogs, then my mom brought a dog from her colleague, to our home. I liked the dog, but I was afraid as well, I wanted a photo with the dog, and my mom told me to touch it. It was ok. Then my mom brought home a toy poodle that was abandoned by its owner, and we kept it until the owner asked it back. After a while, you develop a relationship with the dog, so I paid to adopt a dog myself.

The chocolate colour and grey colour ones are less common than the brown ones, and when they get older, they grew white hair just like humans. Yesterday, I thought 'ah ya ya, a-mi you are four years old, you would be 28 if you were a person, you must grow old slowly.

Then my kid said, a dog lives about over ten years, let it eat whatever it wants, dogs can't eat salty food, if we cook we leave a portion for it without putting salt in it. As they grow older, the grey and chocolate colour toy poodle grow white hairs.

R Oh…they grow white hairs too?

P Yes, they grow white hairs too, mine has got white hairs on mine.

I would shower them one by one every week, they all have their own towels. They are ::so smart::, once they saw me wearing my rubber boots, or blow-dryer, they would hide underneath the sofa.

But they are well-behaved when I wash them. The little one, I let it run around at home, because that's his childhood, he should be happy. He would shake his head, the water will get everywhere, so I carry the blow-dryer and go after it. I haven't learnt how to cut their nails yet, so I dare not to hurt them, I take them to the shop once a month.

R Have you ever trained your dog?

P Training, hmmm, well, this female one is very smart, she can't speak, I tell her, "call me mommy, how do you call me mommy? She would stick her tongue out, if she is in a good mood, sometimes it would act like a princess, like if you feed her, she would be in a good mood, and put out her tongue immediately, if she isn't in a good mood, like if you didn't satisfy her, didn't feed her, she would just lay there, and not respond to you. So yeh, if she is pleased, she would call me mommy. It's not the kind of licking when it wants to be fed, but different, she is really calling me mommy. I would say, give me a paw, (gesturing the dog does it), the other one, then she would switch her front paw. If you throw the gold fish toy out, 'dian-dian, bring it over to grandma", she would run over. Then I pet her, and give her a reward, a little beef treat, then I throw it again, and she brings it back again.

Dogs are good for passing time. Also, I read that dog owners live 5 years longer on average. The environment here is great, always groups of dogs, big ones and small ones. You know how smart they are? You come home, and you mention the names of other dogs, it would bark. You can't mention them, or she wouldn't stop barking, just like a kid that can't speak.

R Besides cute, what other qualities do you like about your dog?_

P Today, when my dad and I are eating in the dinning room. My mom didn't hear when we called her, because of the old age, the dog went to call her.

The other day, there's a story about dog on the TV, she didn't know it's TV, but watched intently. She was so focused. And she really understands when you talk to her. You say, 'I'm going out, to make money for you to get food.' She would always stare at my bag when I return. Now I go out and dine out with friends, I always bring some back for her. She would be very happy, you have to treat her fair, she is like a kid, she understands.

R Would you prefer it to respond whenever you call her?_

P Well, dogs are just like human, if you don't talk to it after a long time…smaller dogs are more clingy than bigger ones. If you come home and hold the smaller one, and not her, she'd bark.

Bigger dogs are able to do things, like these working dogs. Like Border Collie, but smaller dogs have many advantages. I need to think more well-rounded. Smaller ones cost less money, and easier for me to wash them. Today we ate duck soup, and we gave the meat to her. It recognises its own plate, once you put the plate there, she behaves so well. If you sit and eat after a while, without giving food to her, she would bark. The little one won't. They are just so adorable.

R Let's talk about the other robots shown here_

P I like the AIBO, it would carry less smell, dogs, more or less they smell, but it wouldn't apply to robotic dogs. It wouldn't pee outside the mat either.

R Would you think these imperfections affect your relationship with the dogs? If you don't need to feed it?_

P Yes, but if I can play with it, it would be better.

R What about CareObot? What do you think?

P It can bring blood pressure unit is not bad, but I think robotic dog is more interesting. Would it come over if I call it, like if I say Jimmy?]

R Yes, it can be trained to respond_

P Ok, and this (robotic) dog, you can bring it to the bed, also, if someone is afraid of dogs, like rabies, robotic dogs won't have these problems.

R So you are not worried about safety problem of robotic dogs. Would you train the dog if you want to teach it skills?_

P Can it be taught? If so, I would.

R What about ElliQ?_

P The functions are ok, I like how I don't need to hold it.

R Why would you choose AIBO if you think all other ones are also good? _

P Maybe because I have dogs, but the form needs to be better, this one seems j ust plastic. I want it to look like real dog, they look too different. Maybe furs, or you can change it like clothes. If it gets on the bed, you could pet it. I love petting my dog, behind its neck.

R Which one is more important? Form or Functions?

P I like dogs, I don't need the dogs to do anything for me.

R If comparing the robots you've seen in the videos, if they don't have these functions, can only interact and play with you, would you choose any of these?

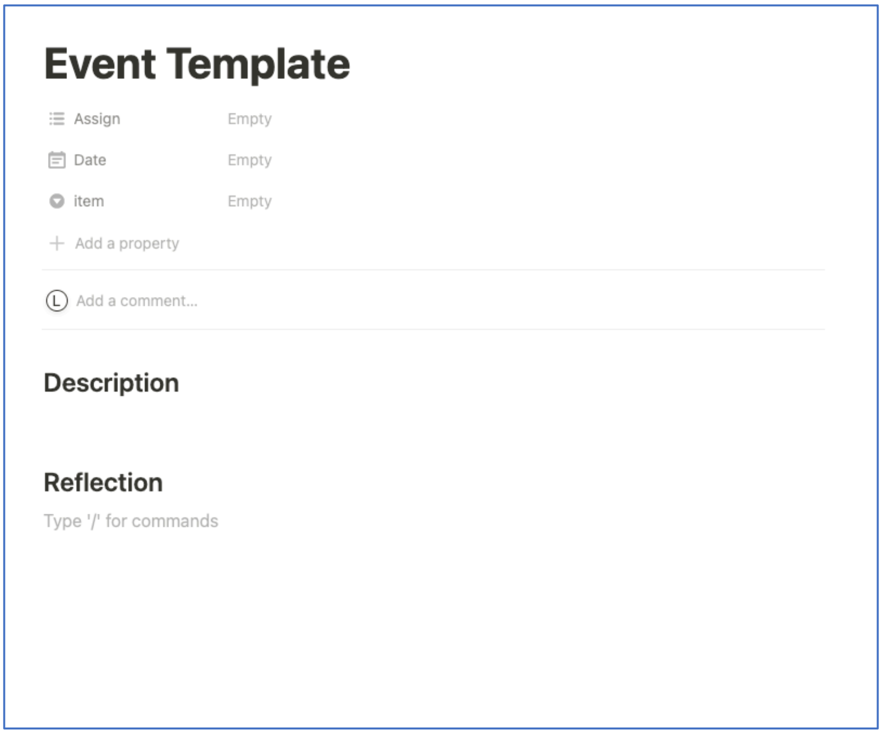
P If the robotic dog has more functions, it would be better, if it can do some things. Hmmm and when you get old, you become child-like again, so playful is most important.

R Which aspect would you prioritise? Form? Function? Or Interaction?

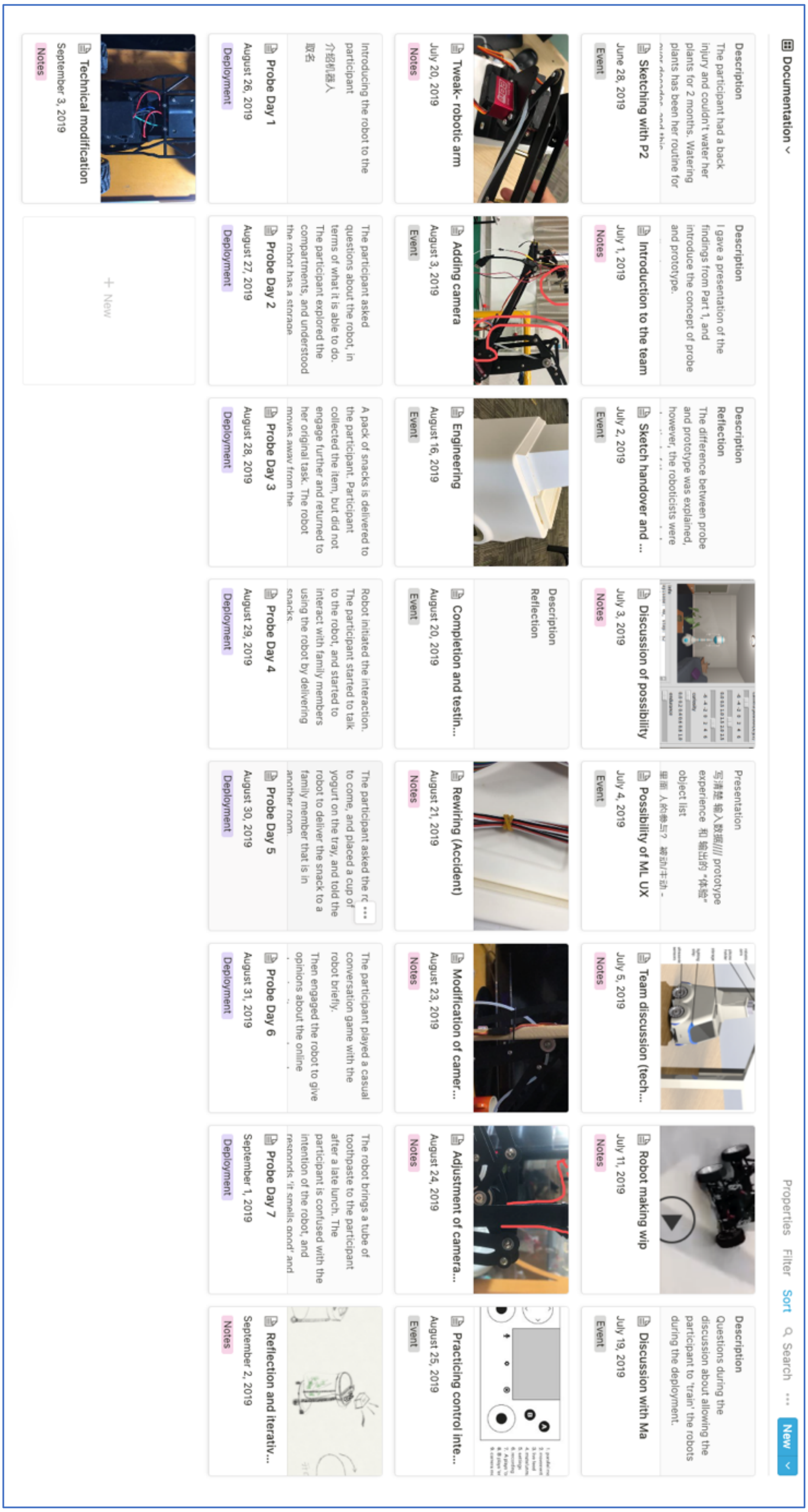
P I think, play and interact with me if foremost important.

3 Appendix 3 Materials used in Study 3 (chapter 6)

3.1 Reflective Design Documentation template



3.2 Screen capture of the overall co-design process using Notion



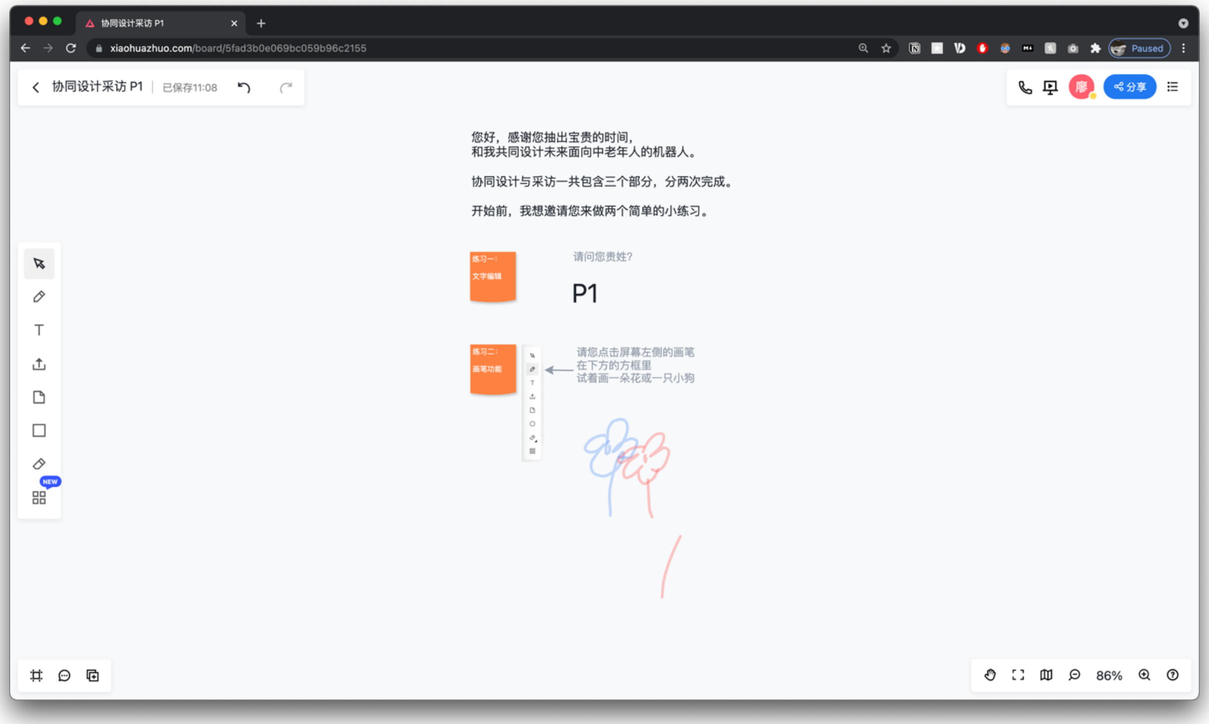
3.3 Videos of probe deployment

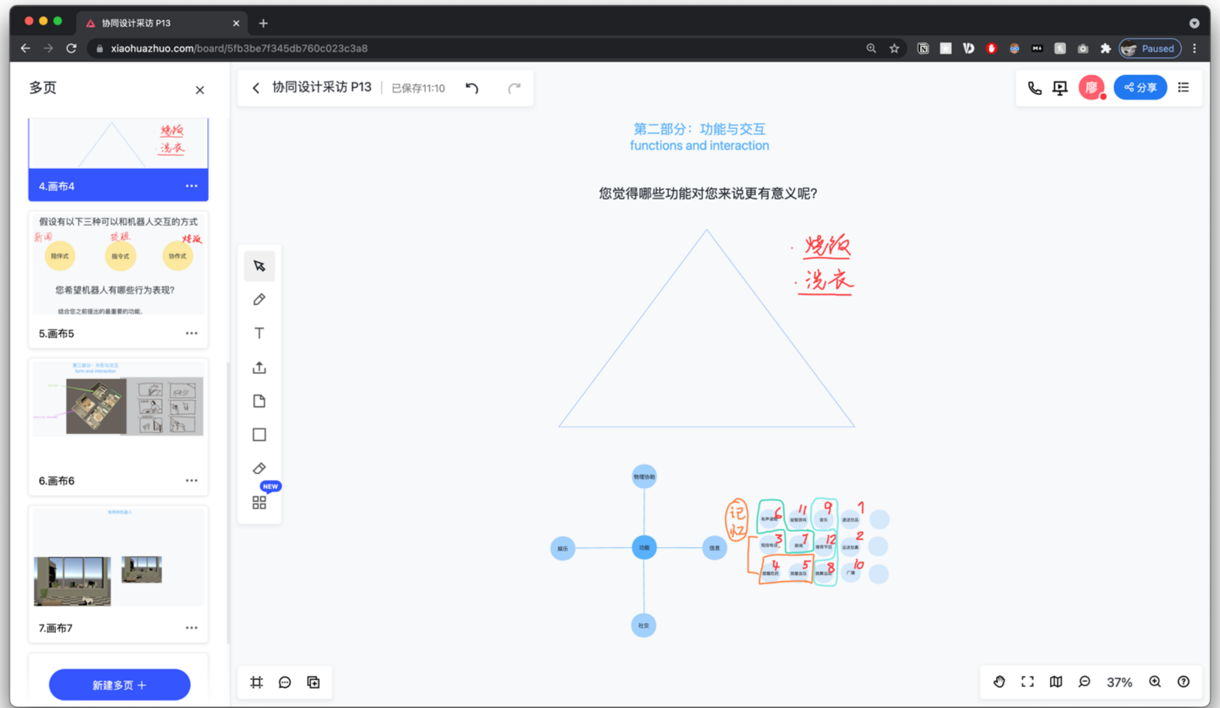
Please see supplement folder in Study 3 Media Files

Study3_ProbeVideo_1
Study3_ProbeVideo_2
Study3_ProbeVideo_3
Study3_ProbeVideo_4
Study3_ProbeVideo_5
Study3_ProbeVideo_6
Study3_ProbeVideo_7
Study3_ProbeVideo_8
Study3_ProbeVideo_9
Study3_ProbeVideo_10

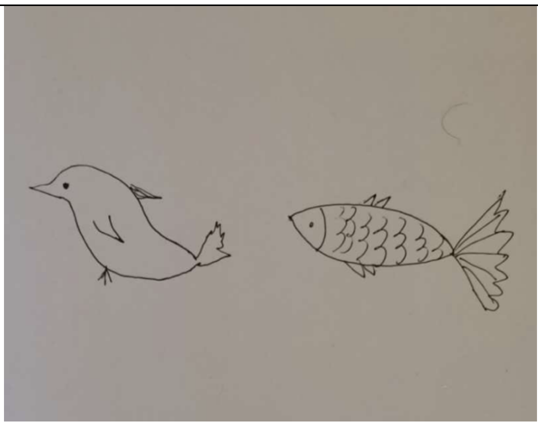
4 Appendix 4 Materials used in Study 4

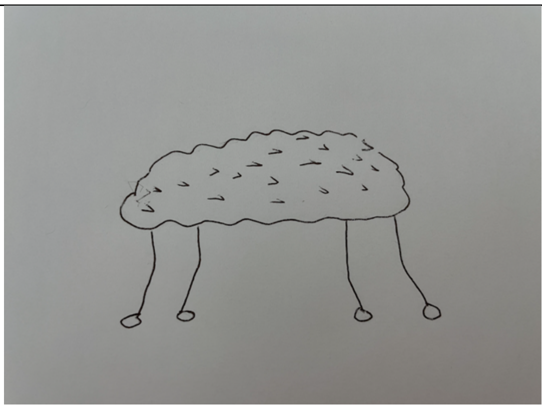
4.1 Online whiteboard space and preparation

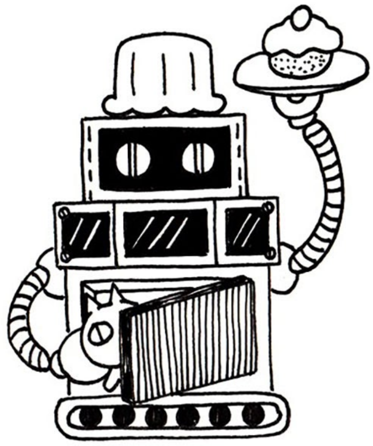
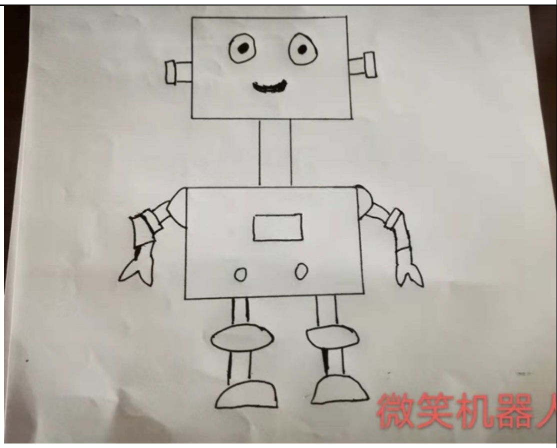
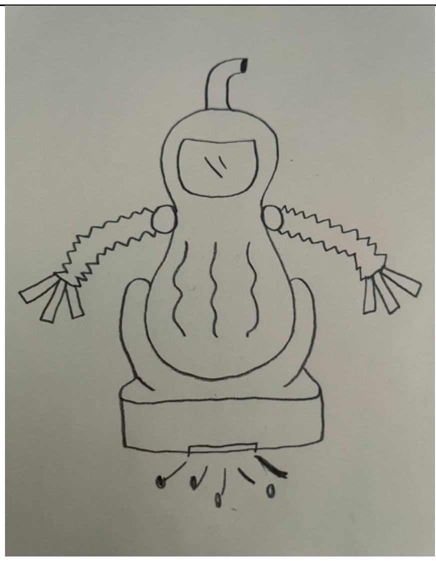




Participants' initial robot concept sketches

P1		The participant proposed a flower-like robot (figure 7-8) because she did not require physical assistance, and preferred a robot that looked less zoomorphic, yet something that fits into a home.
P2		The participant made two sketches of a robot that could bring wonder into the home (figure 7-9). I want something that's not commonly seen in the real world, like something that swims in the sea or flies in the sky. They can bring me on a journey, but in the comfort of my home. (P2 2020)
P7d		The participant sketched an astronaut robot (figure 7-10) to carry out tasks that involve social interaction and caring for a person.

P8d		The participant wanted a dog robot which could learn simple tasks and be helpful around the house. Because it was for the home environment, the participant preferred a pet dog looking robot, rather than a robot resembling a hunting dog.
		In her own ideal robot sketch, the participant expected the robot to be tactile. She considered whether the robot bear was too large, and preferred a footstool sized furniture-like robot that blends in at home. You know, like these super fluffy slippers, but a lot thicker, so it's nice to touch (P9, 2020).

P13		The participant sketched the robot as a maid who can cook and clean at home (figure 7-13). The participant explained that chores at home are foremost necessary. Tasks like cleaning and cooking directly impact a person's quality of life at home.
P14d		The participant then sketched a robot with anthropomorphic features like eyes and a smiling mouth (figure 7-14).
P16		The participant wanted the robot to be able to carry out basic cleaning tasks like Roomba and also to be able to converse verbally with facial expressions

4.2 Animated interactions used in Discussion 3 (section 7.2.2)

Please see supplement folder in Study 4 Media Files:

- Study4_Discussion3_animation_1_dog_behaviour.gif
- Study4_Discussion3_animation_2_dog_form.gif